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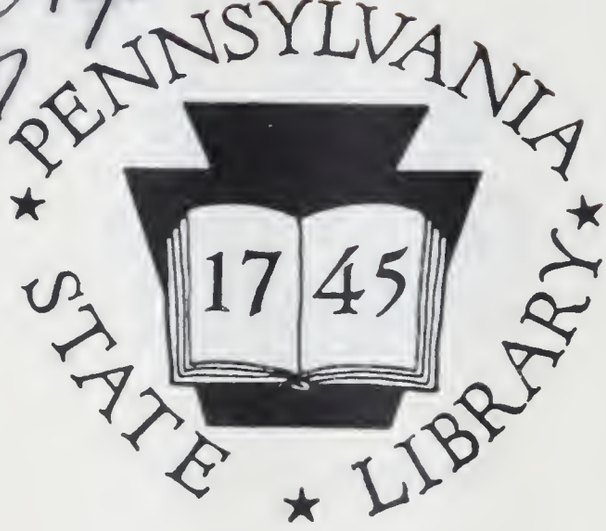

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PERSONAL EXPERIENCES AND MISTAKES IN THE CONSTRUCTION OF SUBSTRUCTURES AND FOUNDATIONS

DESIGNED BY THE AUTHOR

WITHIN A RADIUS OF SIXTY MILES OF PITTSBURGH

By E. K. Morse.*

In presenting this subject before it is not the writer's intention to deal exhaustively with the matter in hand, but rather to pick out enough important constructions to clearly illustrate the more important of the writer's experiences and mistakes, and how they were met and dealt with in their solution.

THE OHIO RIVER BRIDGE.

The first construction considered will be the Ohio River bridge, a highway bridge across the Ohio River, 24 miles from Pittsburgh, Pa., connecting the Boroughs of Rochester and Monaca. This bridge, built in 1895-7, was originally a toll bridge, but was made free by the Commissioners of Beaver County in 1905. The structure is of the suspension type and consists of one twenty-two foot roadway, one six foot sidewalk in the clear, and two street car tracks; the total length is 2 240 ft. made up of a channel span, 800 ft., two suspended arms 400 and 416 ft. each, and 824 ft. of viaduct.

The Rochester abutment and pedestals are of ordinary construction, artificial anchorages had to be provided, and two channel piers built in the Ohio River. The anchorage on the Rochester side was 40 ft. long, 36 ft. wide and 28 ft. deep, the excavation being carried down to firm gravel, 21 ft. below the ground line. The anchorage, built of the same dimensions, on the opposite, or Monaca, side, was on top of the gravel bank.

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*Consulting Engineer, Commonwealth Building, Pittsburgh.

On account of the unequal bank pressure, a triangular nose, 15 ft. on the base, extending across the face was added to the rectangular anchorage, which rested on compact gravel foundation. The two channel piers are composed of Beaver Valley sandstone shell and concrete centers, supported on pile foundations.

Fig. 1. The Ohio River Bridge between Rochester and Monaca, Pa.

The usual method of river pier construction up until this time was to dredge out the river at the proposed pier location from 6 to 12 ft. below the bed of the river to hard gravel, construct a timber grillage of 12 by 12 inch lumber, laid on courses at right angles, of desired width and length, and built up in thicknesses varying from four to eight feet of solid timber. On top of the last course of timber three inch plank were firmly spiked, and calked, and upon this deck an open caisson or box was built and made water tight, in which the masonry for the pier was placed. Usually a timber grillage complete and ready for the masonry floated at the level of the top courses, or if built of hemlock, from one to two feet out of the water, and, as Beaver sandstone weighs about 140 lb. per cu. ft. and fresh river water 62½ lb. per cu. ft., an even course of two foot stone would sink the grillage nearly four feet, if the caisson were filled solid with masonry, which is never done with masonry construction, as it would not permit of pointing the masonry afterwards. As it was impossible to dredge out the foundation footing perfectly level, the writer never succeeded in landing a grillage foundation level, and if a list developed before the top of the masonry was above Pool Full, or low water, as the case might be, it was built out under water, and if otherwise it was built out gradually above water level, but the list at the water level was there, unavoidable, unmechanical and an eye-sore.

These and many other similar conditions, coupled with the fact that an uneven settlement in a suspension bridge

must not be allowed, led the Author to adopt piles instead of a gravel foundation, and a substantial concrete center instead of the common practice of cut stone ashlar for the face and stone and spalls for backing in the center of masonry pier construction. As it had been my previous practice in the erection of bridges to load selected piles to fifty tons, or over, without detecting weakness, it was then considered good practice in construction of bridge foundations to load selected piles practically one-half that amount, so do not be surprised when

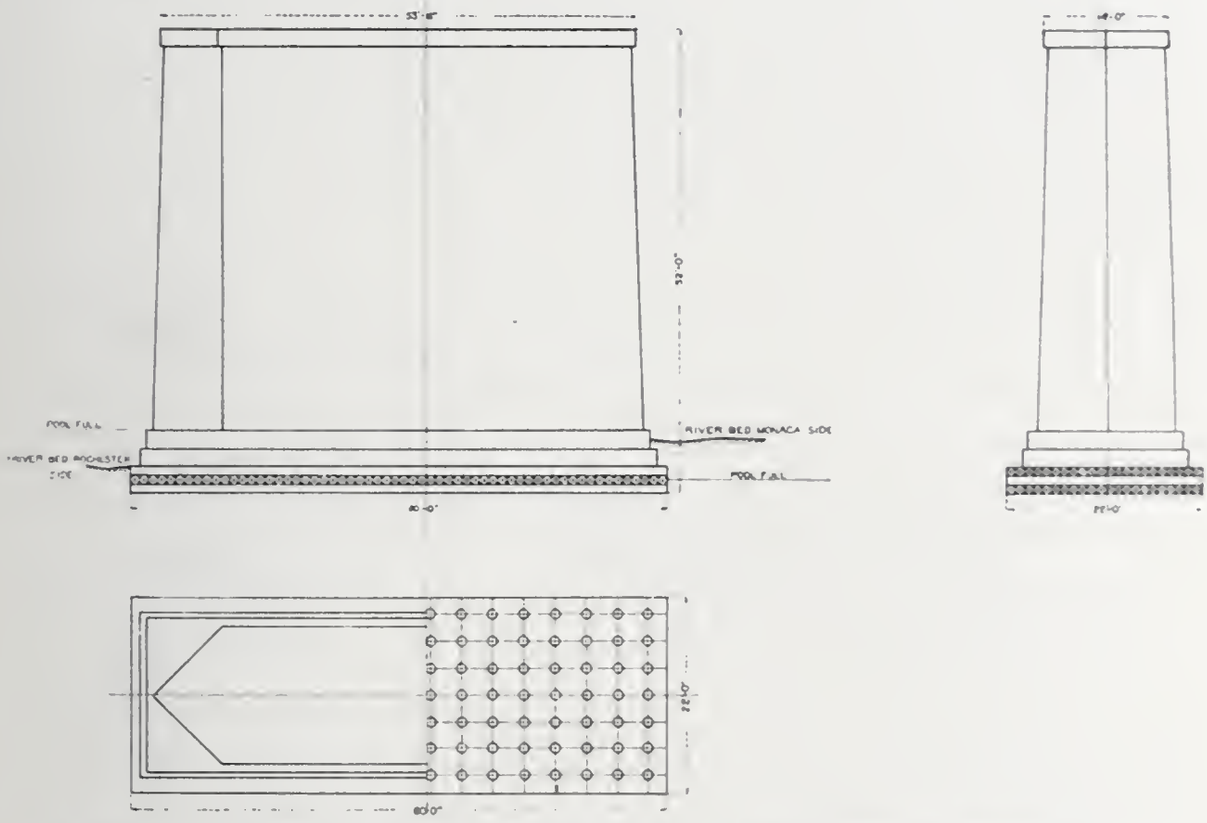


Fig. 2. Typical River Pier of the Ohio River Bridge.

you learn that the load per pile for the 119 piles in the channel pier of the Ohio River Bridge is 56 000 lb. for the dead load alone, and 68 000 lb. per pile for the combined moving and static load.

The piles were selected white oak and pignut, 15 to 18 in. diameter at the top, not less than nine inches at the bottom, straight and sound; the driving was in compact gravel and the distance driven to cut-off averaged about 12 ft. No unusual difficulties were encountered in constructing these two piers.

The contract for the substructure was let in the autumn of 1895. The materials specified were as follows:

Stone: Beaver Valley sandstone.
Cement: Hoffman brand of New York Rosendale.
Mortar: 1:2.
Concrete: 1:2:4 (broken stone).

Work was not started on the Rochester anchorage until fall, and owing to bad winter weather prevailing when the Contractor was ready to begin concreting for the anchorage an American Portland cemented was suggested, and, after considerable misgivings, the Vulcanite Portland cement was selected, a new American cement of unknown and untried qualities; the first

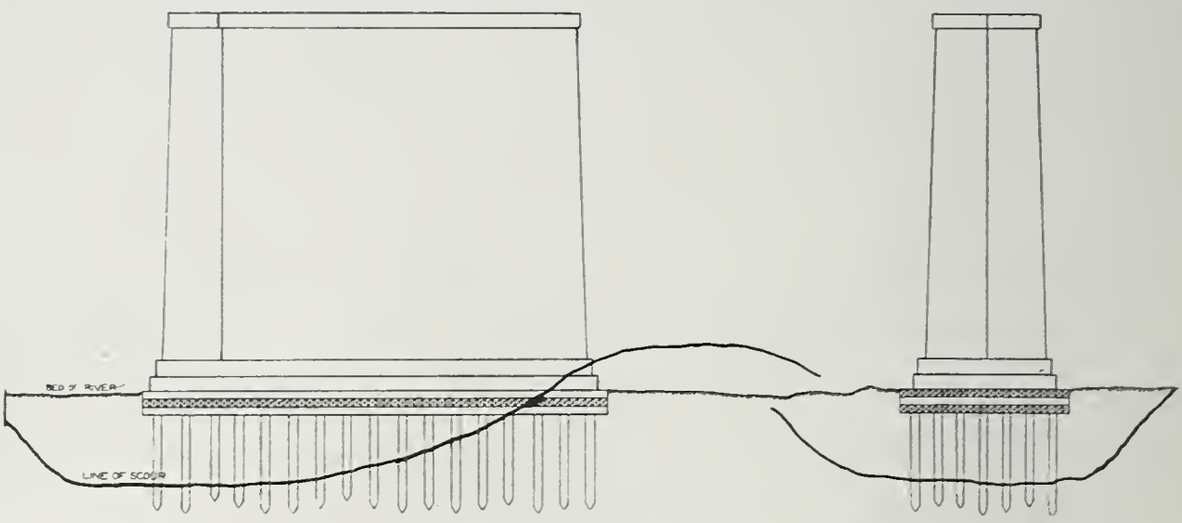


Fig. 3. Line of Scour at one Pier of the Ohio River Bridge.

car shipped into this section was delivered at Rochester and put into the Rochester anchorage, mixed 1:3:6, and the upper half finished with Vulcanite cement. About the same time the Monaca anchorage was started and the lower half constructed of concrete using Vulcanite cement, but about the first of March the weather was considered warm enough to change back to the specifications and consequently the upper half was finished with Hoffman cement. April, May and most of June were cold, wet months. The cement in the anchorage on the Monaca side, after taking its initial set, refused to harden during the month of April. The Board of Directors ordered it removed, and the Author refused to do so, claiming the concrete was well mixed, put in according to specifications and

would harden in process of time. The Contractor for the superstructure would not need this anchorage before July or August and the removal of the concrete involved considerable money. The Author's resignation was demanded and all kinds of trouble developed, but after about six weeks of the most miserable experience of his life there were a few warm days and nights the latter part of June, and before any of us knew it, the concrete in the Monaca anchorage had hardened up and all hard feelings were history.

In February 1897 the bridge was turned over to travel, and on the 21st there was a 29 foot flood in the Ohio river, which scoured under the upper half of the channel pier on the Rochester side to the extent of nine feet below the cut-off, or nine feet below the bottom of the timber grillage, and deposited the gravel scoured out just below the lower end of the pier. This alarming condition of affairs was not known until after the flood had gone down and the bar thus formed below the pier showed above the water. The Author was called to inspect the pier and a half hour spent in making soundings revealed the fact that above the upper half of this pier the river had scoured to the depth of nine feet below the cut-off, and at a point where the piles were only driven, on the average, twelve feet below the cut-off. Fortunatly several scows loaded with gravel were tied up at the Rochester wharf, which were immediately dumped in front of, and around the upper half of the pier where the scour had taken place, other scows of gravel were brought from Pittsburgh, and, after the hole had been filled up level with the bottom of the river, small boulders were placed as evenly as possible around the nose, and upper sides of the pier. No further trouble has been experienced neither has there been any settlement detected or the slightest crack developed in the joints of the masonry. The Company had been urged to place rip-rap around the piers the fall before, but felt it was a waste of money. It will be noted that the low water line is 18 in. below the top of the timber grillage on the pier on the Monaca side of the channel. This was done simply to save money, and with the full knowledge that the underflow from the river and bank were sufficient at all times to keep the timber grillage under water. In the fall of 1896 the

Fig. 4. Denny Bridge of the Bessemer & Lake Erie R. R. across the Allegheny River.

Length of Viaduct.....1795 ft.
Length of Bridge.....1757 ft.

Total Length.....3552 ft.

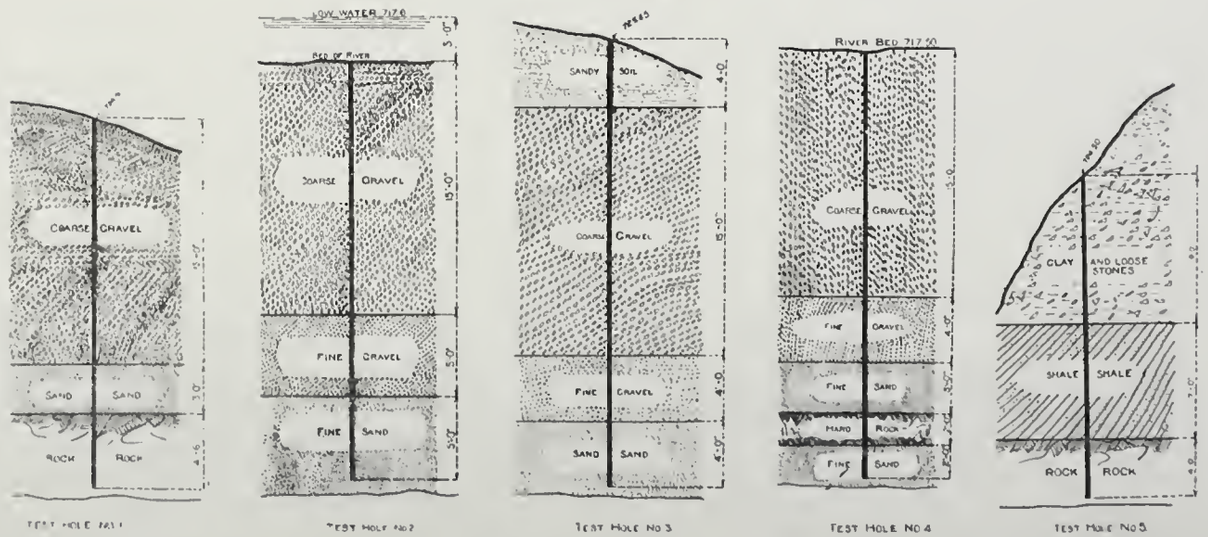


Fig. 5. Test Holes showing Formation at Foundations of Denny Bridge.

extreme low water up to that date was established and at a time when the low water was 18 in. below the top of the timber grillage, a test trench three feet deep was dug out to the then extreme low water a distance of 150 ft. The water flowed freely out of the ditch from the excavations around the grillage, but did not expose the top of the timber.

DENNY BRIDGE.

During the month of May 1896, Mr. F. E. House, chief engineer of the Bessemer & Lake Erie R. R. (Carnegie's Railroad), turned over to the Author the complete charge of designing and constructing the substructure of the railroad bridge across the Allegheny River, near Denny Station, 14 miles from Pittsburgh.

This crossing is for a single track railroad, extending from bluff to bluff of the river banks, a distance of 3552 ft. and as the extreme height of 167 ft. from the top of rail to the bottom of the river bed in the center of the channel span demanded the best of foundations, test holes were made by drilling near the location of each river pier, and the results carefully tabulated.

If ever time was the essence of a contract, it was on this work, and nothing was spared to save time. It was, therefore, thought best to rush to completion the two piers in the river, and follow up with the two shore piers, and the one on Fourteen Mile Island. The piers were located as follows:

Pier No. 1 in a corn field.

Pier No. 2 in the back channel.

Pier No. 3 on Fourteen Mile Island.

Pier No. 4 in the river near Fourteen Mile Island shore.

Pier No. 5 on the left shore.

The drill holes showed the following formations:

Pier No. 1 Rock at a depth of 18 ft.

Pier No. 2 Gravel and sand.

Pier No. 3 Gravel and sand, Rock at 22 ft.

Pier No. 4 Gravel and sand.

Pier No. 5 Shale at nine feet and rock at 16 ft.

The crib style of construction was decided upon around piers No. 2, and No. 4, the deepest water being at No. 2, where there was only four feet at low water. It was also decided, where possible, to drive piles, cut and capped with 12 in. by 12 in. oak timbers, concreted around and up to the top of the cap. At piers No. 1, 3 and 5, where rock was expected, excavation was to be carried down to the rock.

Pier No. 2 was started first and completed during the spring of 1897 and while preparations for No. 4 were being made, excavations for No. 3 were started, and, to everyone's surprise, cemented or hardpan, gravel was met with under 21 ft. of soft loamy sand and gravel. A jumper drill hole showed the formation to be over eight feet thick, and No. 3 pier, 87 ft. high, was built on this foundation, without a sign of settlement. Pier No. 4 followed No. 3, and was built during the same winter, 1897. At one time during the latter part of January some 20 ft. of No. 4 was laid in weather from one to seven degrees below zero, with the outside of the pier frozen solid, the concrete core apparently not taking its initial set. The Author saw an inch pipe, 16 ft. long, pushed by hand its full length into the mushy concrete in the center of this pier. Something had to be done, and no one knew what was proper. Vulcanite cement was specified, and the tests made at the site were entirely satisfactory. It was finally decided that the Contractor should cover the masonry with two large tarpaulins, and turn steam under them during the night, and see if thawing out the masonry shell would help matters. By morning the masonry was warm, and the concrete in the center had started to harden so nicely that the steam sweating was kept up 24 hours longer, when work was started again. No further trouble of this nature was experienced and when it came to pointing the masonry the following summer, it was found that the mortar in this pier could not be removed and cleaned out as easily as in the other piers, so hard had been the set.

Nothing out of the ordinary was met with in the construction of No. 5, and the foundation met with was exactly what was anticipated.

Excavation for pier No. 1, located in the corn field, was considered as simply a question of digging down 25 ft. to rock, which showed in three drill holes to be nearly the same elevation on each shore, and was verified in exposed rock formation on the east, or left bank of the river. Instead of finding rock a semi quicksand formation was met with that gave all kinds of trouble. Finally 280 piles were driven in the hole at an

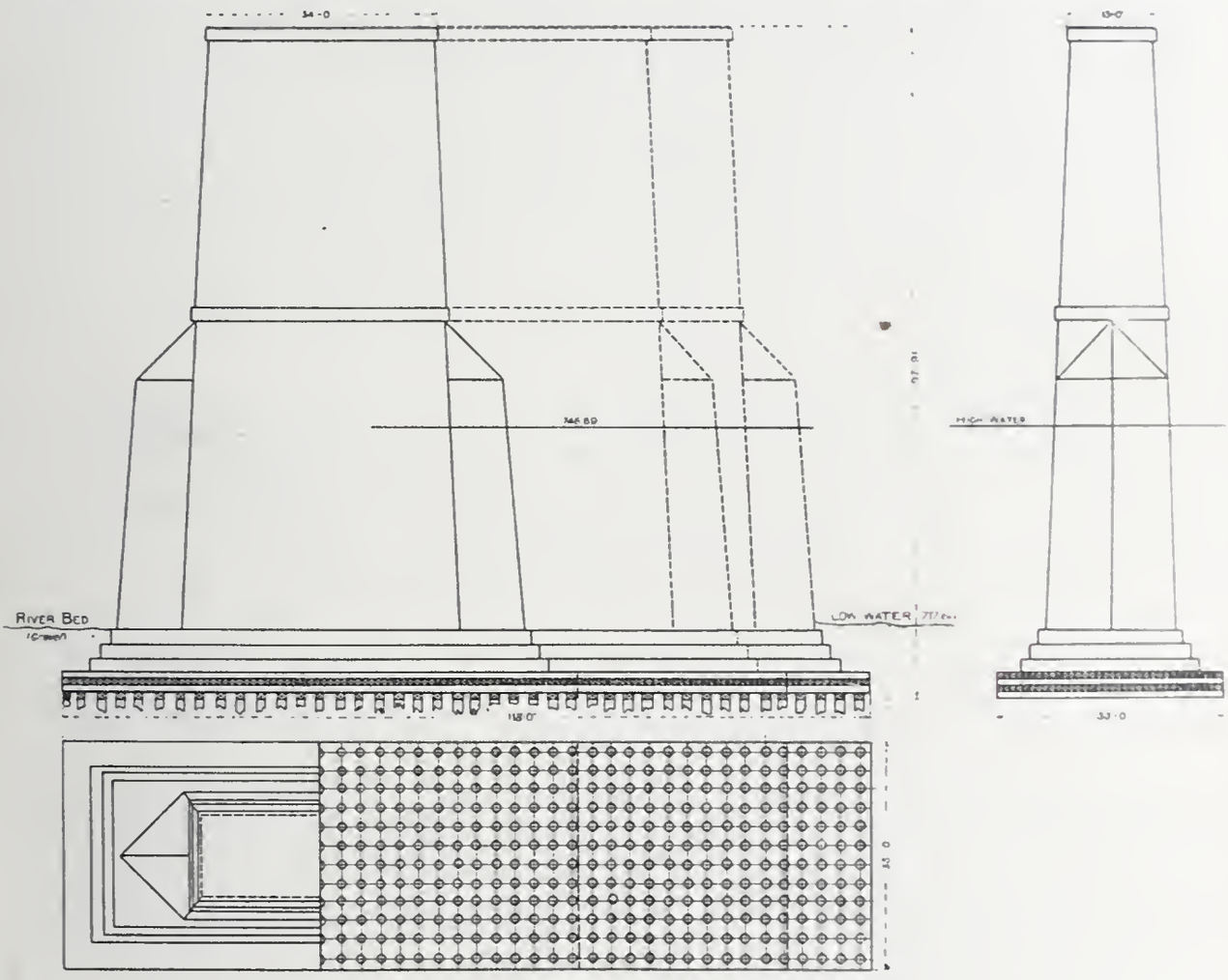


Fig. 6. Pier of the Denny Bridge.

additional cost of piles and extra concrete and masonry amounting to a large sum of money. If test holes had not been drilled, piles would have been designed for every foundation, except that of Pier No. 5, and the exception would have been No. 3 on hardpan. This is the only case known to the Author where a hardpan gravel formation has been met with underlying an island in the middle of a river.

The error was in not having test holes drilled at distances not to exceed 200 ft. apart from shore to shore. At drill hole

No. 1 and 4 the rock drilled into was, no doubt, one of the many granite nigger heads so frequently met with in excavations for No. 2 and No. 4 piers, deposited there during the glacial period.

PORT PERRY BRIDGE.

On the last day of June 1897 the organization at Denny was moved to Port Perry on the Monongahela River, 14 miles above Pittsburgh, to take full charge of the construction of the foundations for Carnegie's Hot Metal Bridge, connecting the furnaces at Bessemer with the Homestead and Duquesne mills. Mr. F. E. House, Chief Engineer of the Bessemer & Lake Erie R. R., and consulting engineer for W. H. Smith, chief engineer of the Union R. R. decided that test holes drilled the same as at Denny were quite the proper thing, and the Author's in-

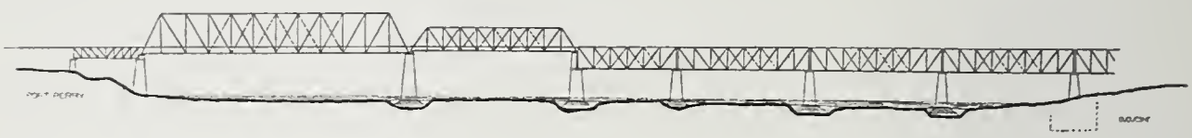


Fig. 7. Port Perry Bridge of the Bessemer & Lake Erie R. R. across the Monongahela River.

structions were to proceed and put down four holes all in the river, which, as anticipated, showed gravel and sand formations. The plans approved by the War Department called for seven piers. The first, pier No. 1, was located on the right bank of the river, or the Bessemer side, on the shore line 46 ft. from the south bound track of the P. Mc. & Y. R. R., and pier No. 7 on a sand beach on the left bank. The plans and specifications called for a pile foundation, cribbing, and back fill sufficient to set the masonry below the Pool Full line, which was to be kept dry at least 24 hours before allowing the water to cover it. The object to be attained was to cut the piles by hand at the desired elevations, capping them and concreting around and up to the top of the cap, upon which pier masonry would be laid.

Pier No. 1 was excavated and the hole kept pumped out. Excavation was started in pier No. 7 at the same time, as it was planned to get the foundation in and up to the top of

the ground while dredging, pile driving, and cribbing were progressing on the river piers.

Pier No. 6 was gotten ready first, and an attempt made to pump it out without results. On account of the double Wakefield sheeting leaking, gravel and sand were dredged and deposited up and around the outside of the sheeting, first to a depth of nine feet and later to Pool Full, a depth of 18 ft., and with pumps of a capacity of 16 000 gal. per min., running for hours, the water in the inside of the crib could be lowered only two feet below Pool Full. Beautifully filtered water boiled up through the gravel formation of the bottom. An attempt was then made to seal the bottom by depositing a few

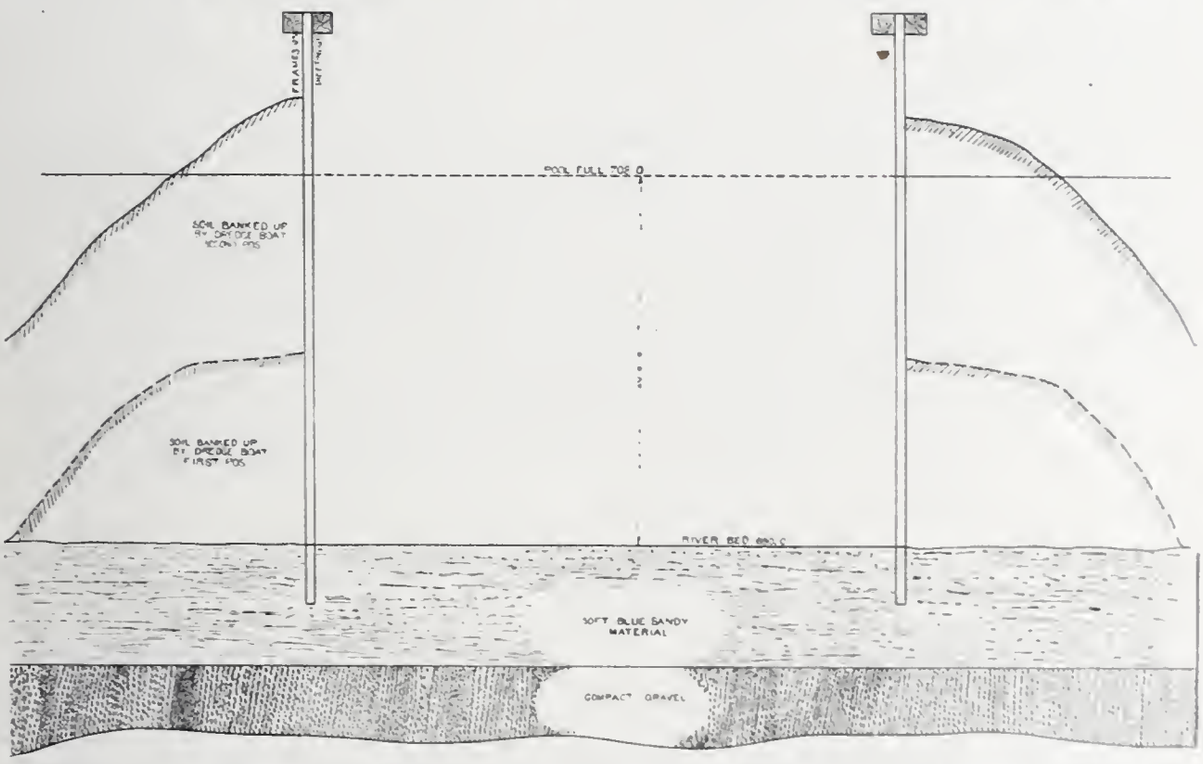


Fig. 8. Section of Crib at Pier No. 6, of the Port Perry Bridge.

feet of concrete, (deposited through a pipe lowered down to the bottom of the hole and moved about by a diver) expecting to place about two feet of concrete evenly over the whole bottom. It was discovered at once the concrete lowered through a pipe washed sufficiently to allow the cement, sand and gravel to segregate, and the results were so poor that the attempt to seal the bottom was abandoned. Pier No. 6 was abandoned and piles for No. 5 driven, cut off under water by power, concrete lowered and placed around the piles by marine bucket, and

the concreting pushed night and day. All unevenness of the concrete above the tops of the piles was leveled off by dragging a heavy I-beam across the concrete while green, and as soon as it had hardened, a timber grillage was sunk upon this foundation, and the masonry brought up to Pool Full, by means of open caisson with such good results that it was decided to construct all the piers, wholly within the river by this method. The sheeting and filling on the lower half of No. 6 was removed, and piles driven, cut and concreted the same as No. 5, and afterward a caisson was floated into position, and sunk as in the case of No. 5, No. 4 and No. 2.

It had been the practice in constructing a grillage to first use 12 by 12 white pine timbers, later hemlock throughout. The great weight of the masonry, steel work and moving load concentrated on tops of the piles frequently caused an uneven crushing of the bottom timbers of a grillage with the result that this uneven settlement either developed cracks in the body of the masonry or a list in the whole pier, which had to be built out. It occurred to me that the crushing of the soft timbers of the grillage over the top of a hardwood pile could be overcome by adopting the plan of using 12 by 12 oak timbers for the first or bottom course of the grillage, which completely corrected the trouble.

It had been customary up until this time to mix concrete so dry that it required hard tamping to bring water to the surface, but on No. 4 the mix was made sufficiently wet to flow, and disturbed the cement manufacturer to such an extent that threats were made that shipments would be stopped if such abuse was not immediately corrected. The discussion grew so warm that it was decided that it would be tried out in the following manner. For a distance of about ten feet above Pool Full in Pier No. 5, the concrete in the center of the pier was mixed just wet enough to show water on the surface after ramming, and in No. 4 the concrete for an equal distance above Pool Full was mixed so wet it flowed and would not support the weight of a man. These two piers were then allowed to season for about two weeks, and the agent for the Portland cement

invited to come from Philadelphia to Pittsburgh and decide for himself. His decision was "Well, this is astounding." He had seen the cement go into Pier No. 4, had marked the work and knew there had been no deception.

Fig. 9. Formation at Foundations of Port Perry Bridge.

The condition of the concrete in No. 4 was by far superior to that in No. 5. Apart from the fact that there could be no voids in concrete mixed so wet it had required no labor for tamping, usually two men to each pier under construction, and it was just that much cheaper to the Contractor, an item that no Engineer must allow himself to neglect, which is always due the Contractor, and which if willfully refused reflects cowardice and dishonesty on the part of the Engineer. All concrete thereafter was mixed wet.

One morning, after No. 4 had been carried up to an elevation about 15 ft. above Pool Full, great fissures and cracks extended diagonally across the top of the pier, and down each

side to water's edge, opening a few joints, but in most cases breaking the stone, plainly showing the pier had broken its back. There was nothing to do but to remove the stone and concrete, float the caisson and send a diver under the grillage to discover the cause of the trouble. When it came to removing the concrete that had been put into position wet, though comparatively green, it had to be dynamited. As soon as the caisson floated the grillage about two feet a diver was sent down, and reported that a pile had found its way under the grillage just before landing same on the piles, and that it was located near the center of the foundation. The grillage was strong enough to support the masonry until the full weight of the masonry in the air crushed the timbers over the pile. The Contractor had his diver examine the condition of the hole and piles for No. 4 just before the caisson was floated into position, and the laying of masonry in same started, but the mistake was made in not sending the diver down again just before drawing the plugs of the six or more 3-inch holes in the sides of the caisson through which the water is allowed to flow freely, and in a few minutes sink the caisson into position on the piles.

The current in any of our rivers is sufficient to roll submerged timbers into the holes dredged out for such foundations. In this case it was one of the Contractor's own piles that had gotten away, sunk and was probably washed under by his tow boat, which was constantly delivering materials.

The design for Pier No. 7 called for 20 ft. of excavation. After about 12 ft. was excavated a semi-quicksand was met with that proved too interesting for the Contractor. The hole inside the cribbing was 20 ft. wide by 84 ft. long. Repeated efforts were made to pump out the crib sufficiently to enable the excavation to proceed. Quite often the bottom would be exposed for a few minutes, only to have the water boil up all over the bottom, from mounds like the ant colonies near Hollidaysburg, and they suddenly stop, only to break out in a few minutes at some other point. The problem was finally solved by driving all the piles for this pier, (176), from the top, sheet

off the pier into four equal compartments, pump out one at a time sufficiently to complete the excavation, cut off the piles, clean up the rubbish, cap the piles and concrete up to the top of the caps, and in this way possession of the pier was gained, and the balance of the pier completed according to the original specifications.

The question may be quite properly asked, did the Author ever have any river masonry built in exact accordance with his plans and specifications, the answer must be emphatically, No! The Contractor could have been forced to build all seven piers for the Port Perry bridge in exact accordance with the plans and specifications. The result would have been that a fortune would have been sunk in the foundations. The commercial value to the railroad company would not have been any greater, a year longer would have been required to complete the bridge, and as it turned out money was actually saved by changing the plans and specifications to suit the conditions met with in actual construction, for it was not until then that it was clearly shown that the old channel was close up along the left bank of the river, and not over on the right side where the Government locks are located. Shallow water is now met with where once there was a channel from 20 to 30 ft. wide. This soft fill on the left side is what caused most of the trouble. There is no denying that the Author's plans were also at fault in specifying such foundations so long before the days of steel sheet piling.

The originally desired results would easily be obtained today by dredging out to the required elevation, driving piles, sawing them off under water, and then driving modern steel sheet piling around the piles as driven and cut off, and depositing material from the bottom of the river around the outside of the steel sheeting up to Pool Full, and finally placing from four to six feet of concrete around the piles with marine bucket, thereby forming the base, or first footing course of the pier, pumping out the water in the inside after the concrete had set and completing the masonry with ease and precision.

MOSGROVE BRIDGE.

There is a hard sheet of gravel about three feet thick in the bed of the Monongahela River for a distance of 55 miles from Pittsburgh, under which the formations are alternately soft and hard down to rock. In the Allegheny River, however, the condition of the river bed is compact gravel with boulders from the Ohio River to Oil City, 133 miles. There is a decided ground flow, below the bed of the river, of hard water, due to the many beds of limestone throughout the length of the river, together with frequent indications of more or less extensive deposits of soluble silica, which may be the explanation of the tendency towards hard pan gravel so frequently met with.

Although there were no such beds of hardpan met with in the construction of the substructure of the B. R. & P. R. R. bridge across the Allegheny River at Mosgrove, 55 miles from Pittsburgh, as at the Denny Bridge, it is, nevertheless, interesting to review the experiences on that work, especially the river pier masonry.

Excavation for pier No. 2 was started in July 1898, and carried down eleven feet below the bed of the river. Sheeting was started, but the Contractor discovered that the gravel was literally glued together, stopped the sheeting about five feet below the surface, and never drove it any further.

Although the excavation was carried four feet below the bed of the river in the channel, there was scarcely any water in the hole. During the driving of 288 piles for this foundation the constant jarring never sluffed down any of the six feet of exposed gravel on the sides and ends. This cheese-like condition and action of a gravely loam formation, out of 72 piers built within a radius of 60 miles from Pittsburgh, stood up under rough treatment as no other had. You will also note the ground flow was not in evidence. At pier No. 3 in shallow water the conditions and results were the same.

Pier No. 4 was located at the front of a rapid riffle in two feet of water at low water stage. A rough log crib was built around the proposed pier, outside of which piles were driven supporting a timber frame and sheeting, all back filled with

gravel about six feet above the bed of the river. No trouble was experienced in keeping the water pumped out and excavating to the specified depth of eleven feet below the bed of the river, and notwithstanding the gravel removed was so compact and the excavation so difficult, the Chief Engineer ignored good advice and decided to have piles driven and his instructions were followed. The piles in the first row were driven only five or six feet, the driving was hard, the piles when released from the leads of the pile driver would not stand alone, and were actually nailed together, and braced to the cribbing until cut, capped and concreted level with the top of the caps. The hard pounding necessary to drive the first row of piles so shook up the compact gravel that the balance of the piles drove easier, the heaving up of the gravel became greater, and a splendid foundation was converted into one no better, if as good. Considerable money was expended for piling and the additional concrete base that should have been saved. There are times in one's life when one is the sledge and gives the blows, there are also, times when one is the anvil and must gracefully receive the blows.

THIRTIETH STREET WALL.

After completing a wall along the right of way of the P. McK. & Y. R. R. and by the Jones & Laughlin Steel Company double storage mill at 30th Street, South Side, and while foundations were being completed for expensive machinery, it was decided to make a direct connection under the retaining wall, the main line tracks of the P. McK. & Y. R. R. and their Thirtieth Street yard to the Monongahela River for sewage and water.

There was nothing out of the ordinary in laying the sewer and water pipes until the excavation reached the inside, or mill side, of the above mentioned masonry wall, when a bed of black sand of a semi-quicksand tendency was met with that was too soft to excavate and finally flowed so freely that a centrifugal pump handled it like so much muddy water. The Contractor was warned against removing this soft sand, but remarked that he was responsible for the integrity of the wall, founda-

tions, etc., and if they were damaged he would make them good. Additional centrifugal pumps were connected up, and, after pumping out sand and water for about 48 hours, the wall and foundations for a radius of about 50 feet all slowly settled about three feet. An expense of not over $100.00 in driving three-inch plank sheeting would have saved the Contractor several thousand dollars. This case is especially interesting in pointing out to the younger engineers the impossibility of specifying with absolute certainty what material will be met with in construction of substructures. Here was a case where the Author had been several years personally designing and looking after all kinds of foundations, some of them massive, all around this site, and, yet, at the least expected place a bed of semi-quicksand was met with, that with the addition of water was actually made soft enough to remove by centrifugal pumps.

VESTA COAL COMPANY WORKS.

The rapidly increasing demand for blast furnace coke necessitated the Jones & Laughlin Steel Company opening up Vesta Mine No. 4 on such lines of permanent construction and capacity of output as had never before been attempted in this country. Everything was built to last forever and then some. The main entrance was two miles from the river front. Apart from one slight curve it was an air line of tunnels, bridges and viaducts. The experiences with small foundations, slips, creeping hills, broken roofs in old workings, etc. met with in these two miles, was sufficient in itself for a paper, but as your attention has been confined principally to river pier construction, it will be confined in this case to the river pier at the tipple for crushing and loading the coal into barges ready for towing to the works in Pittsburgh. This pier is situated on the left bank of the Monongahela River at California, Pa., 50 miles from Pittsburgh.

This pier was designed large enough on top to accommodate engines, crushers, motors, etc., besides supporting an elaborate steel tipple, which required a pier 20 ft. wide by 60 ft. long on top, with the river face smooth and vertical, and the first off-

set ten feet below Pool Full in order to always provide ample clearance for floating craft fully loaded. In order to accommodate the maximum number of empty and loaded barges, the pier was located on dry ground wholly within the shore line, necessitating cutting into the slope. The center of the pier was located 100 ft. from the center line of the north and south bound tracks of the P. V. & C. R. R., and the cut-off of the pile foundation for the pier 54.8 ft. below the top of the rail. The railroad tracks were 34 ft. above Pool Full on natural ground, composed of sand for the first 12 or 15 ft., and stratifications of clay and sand to the water line, a bad omen. Every Contractor bidding on this work was well aware of the fact that trouble could safely be predicted, as it was a shore pier, on account of the geological formation and because the Pennsylvania R. R. tracks were laid on the very edge of the bank, with a sharp curve towards the river, and a bad grade at this particular point.

The Company had even invited each bidder to estimate on a *V* shaped permanent pile fender to be driven on the slope of the river bank. Everything went smoothly until the dredging was nearly completed, when the resident engineer saw the material dredged out, black sand and gravel, did not materially reduce the depth of the hole; the material was flowing in as fast as it was being dredged out.

The *V* shaped fender of piles had been put in the specifications by the advice of the Author with the full belief this device would effectually prevent any caving away of the bank while putting in the pier. The Contractor was to assume all responsibility in sinking the foundation and incorporate in his bid any additional protection he saw fit, which was written in both the specifications and contract, and written notice given at the time proposals were asked, which is quite the exception.

It was perfectly plain the dredge had reached a dangerous bed of semi-quicksand. The Contractor's attention was promptly called to the danger, but with no effect and the dredging proceeded. About midnight the second day following, without a moment's warning, the dredge boat was shot half way across

the Monongahela River. The whole bank slid into the river, four gondolas loaded with stone on a siding back of the pier site were buried in the hole, the northbound, main line, track was gone, the southbound track was undermined, sand, stone, gravel, cement, timbers and tools all were dumped with the gondolas into the river.

After weeks of wrecking and dredging out the tangle, together with great loss to the Contractor in time, material and three gondolas never recovered, double sheeting was driven on the bank side, and a strong framework of piles, timber and sheeting placed on the two ends and river side. The site was then excavated down to the proper depth, and the pier completed according to plans fully six months after it would have been had the Contractor driven sheeting around the hole and acted promptly on the friendly advice given him when the flow of semi-quicksand was first discovered. Simply because he had never had any experience of his own he would not listen to what had been the experience of others under like circumstances. Fortunately this is the exception, rather than the common practice of Contractors.

THE NEWELL BRIDGE.

The habit of traveling, or rather the cultivation of the habit, was never better illustrated than in dividends from the construction and turning over to travel on July 4th, 1905, the Newell bridge across the Ohio River, connecting the Borough of East Liverpool with the bluff on the opposite side of the river.

In excavating for the artificial anchorage in Liverpool, hardpan gravel was found about five feet above the elevation intended for the bottom of the foundation. A careful examination showed this formation was about three feet thick, extending over a considerable area. Concreting was started from the top of the hardpan with excellent results and considerable saving of money. The channel span was 750 ft. center to center of the two channel piers. The pier on the Ohio side was on a bar uncovered at low water. The foundation consisted of piles driven and cut off two feet below the gravel bar, and well concreted around and up to two feet above the cut-off, upon which a masonry shell and concrete center pier was built. The rock

was exposed all along the shore on the West Vrginia side and soundings showed level rock bottom at the site for the channel pier on this side of the river. The plans were drawn for rock bottom construction.

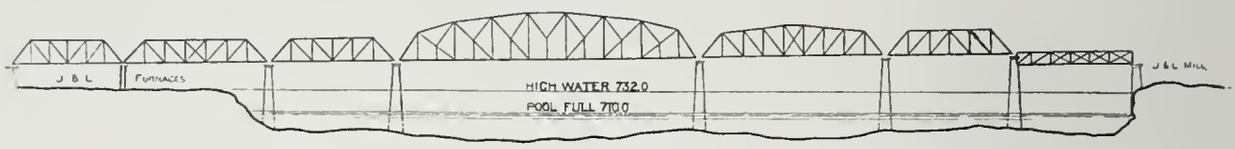
Double cribbing, 3-inch plank sheeting, and suitable fill between and outside same were made, preparatory to pumping out the crib and starting the foundation courses. When the water was pumped out, and the bed of rock exposed, it was discovered that the bed of the river was as nicely paved with large flat stones as any of the stone paving in the streets in older New Orleans, or of the old Roman pavements. The stone averaged about 16 inches square by 12 inches thick, closely laid, smooth and even on top, just the same as if the Romans some day had paved and used the bed of the Ohio river for a great highway, a second Appian Way. There was nothing to be done, but to remove this paving, under which was an irregular formation of smaller stones, sand, gravel and mud. Solid rock was obtained on the upper end five feet below the paved bed of the river, and three feet on the lower end, the stratification of the solid rock dipping about ten degrees down stream. So often does the familiar German adage, "Man proposes but God disposes," come true.

The only explanation for this unexpected, and certainly unlooked for formation the Author can make is that he personally sounded rock with a one inch rod, not only at the site of the pier but all around it. The ring of the steel sounding rod unmistakeably indicated rock, yet, later developments showed a pocket in the real rock which had been filled up with stone, sand and gravel irregularly placed in ages past. Blocks of stone had slid along the rock bottom above the pier site until finally one after the other the heaviest blocks had become wedged together, which formed as nice a piece of paving as if done by skilled mechanics.

JONES & LAUGHLIN STEEL COMPANY HOT METAL BRIDGE.

In 1887 the Eliza Furnaces were connected with the mills on the Southside by the construction of a single track railroad bridge across the Monongahela River, in the City of Pittsburgh.

During the winter of 1900, it was decided to extend the piers down stream sufficiently to allow the old bridge to be double tracked, and also accommodate a single track hot metal bridge; the former connecting the two yards at grade, and the latter elevated in the Southside mill yard. The bottom of the foundations of the old piers had been originally about nine feet below the bed of the river, but owing to constant encroaching on both sides of the river, the bed of the river in the channel had scoured until the bottom of the river was two feet below the bottom of the timber grillages of the channel piers. The plans for the extension called for river pier masonry on pile foundation.



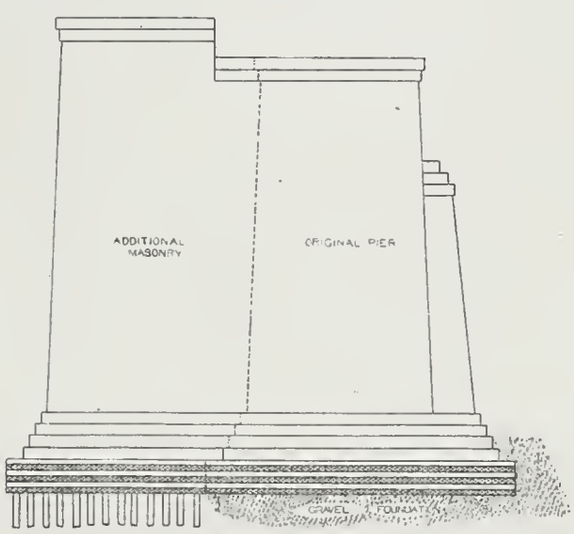


Fig. 10. Hot Metal Bridge of the Jones & Laughlin Steel Co. across the Monongahela River at Pittsburgh, showing River Pier.

The rip-rap protecting the old piers was removed from the lower half of the piers down to the bottom of the grillage, piles driven and cut off at proper elevations and open caissons floated into position and landed close against the grillage of the old piers. As soon as the new masonry was brought up to Pool Full it was arched over to the top of the last footing course of the old masonry, and the new masonry built against but not

joined to, the old piers, and completed according to plans. Of the six new piers, four were entirely within the river. No trouble was experienced though there was one item worth your attention, and shows why no two foundations in the same bridge are exactly alike. Several piers had been completed without more than ordinary care being used, and with no more than the usual amount of trouble always met with. The piles were driving hard clear across the river. The pile driver had finished the upstream half of No. 4 pier using large, straight, carefully selected white oak and pignut piles, today specifications read, "Any hardwood piles that will stand driving" when without the slightest warning a spot was encountered, so soft that the 40 ft. piles literally sank out of sight.

Longer white oak piles could not be gotten in the market and after doubts and misgivings, the Contractor was allowed to substitute long leaf yellow pine sticks 18 in. diameter by 60 ft. long, almost without taper, driven home, first passing through about 12 ft. of soft material and then averaging 12 ft. more in compact gravel.

SUMMATION.

Only enough foundations have been described to clearly demonstrate some of the more common mistakes, experiences and methods of construction, trusting that the younger engineer may be spared from duplicating them. We often hear and read of the successes, but no one enjoys explaining his errors, and perhaps the Author would not do so now were it not that he feels it a duty to the Society, which has so honored him. Be this as it may, conditions are so constantly changing that the greatest of our experiences are all too soon classed as history. Twenty years ago all piers within the 60 mile limit, especially in our navigable rivers were placed in position by dredging out the bed of the river, constructing a timber grillage and landing same by the open caisson process. On account of the unsatisfactory results, due to uneven settlements causing unsightly listing of the body of the pier and opening of joints, this method gave way to the method of dredging out the hole as formerly, but driving and cutting off piles and landing the timber grillage by the open

caisson process, which was universally adopted in deep water and navigable streams, from about 1896 until 1905. The rapid rise in the cost of hemlock timber and the desire of the engineer to be foremost in reforestration, led to the substitution of a concrete base for the timber grillage.

The introduction of steel sheet piling enables the Contractor to drive it around wooden piles, that have previously been driven and cut off, or driven by follower to a close approximation of the cut-off elevations, forming the desired rectangle for the concrete base. The day has come when the concrete pile in this style of pile foundation will take the place of the wooden pile, and it can be easily accomplished with perhaps the necessity of using one wooden test pile to determine the exact condition of the formation of the river substratification. Steel sheet piling has been a great step forward in that it will stand driving where wooden sheeting would fail, that it is comparatively easy to drive it to a true line in closing the rectangle for the base, that its strength results in a consequent saving of bracing and comparatively easy manipulation of the buckets of concrete placed in the bottom, and that the danger of collapse from added pressure of high water, and loss by being flooded out are almost eliminated. It must be admitted, however, that the first cost is considerable and the damage to sheeting great in driving through the hard gravel generally met with in local and river pier foundations, and the scrap value is correspondingly small.

Steel piling will often pass through an obstruction that would arrest wooden sheeting. On the other hand the Author has seen steel sheet piling for a shore pier on the Donora-Webster bridge, across the Monongahela River, 35 miles from Pittsburgh on the Webster side, the sheeting opened and lapped past in three places in blue clay, 20 ft. below the surface. In another pier of the same bridge the same weight sheeting drove through compact gravel to a true and even line without a single section opening. There should be an explanation, but the Author has not had experience enough to make it, though it may be due to lack of care in driving.

Some of the best and most lasting monuments in masonry

construction were constructed of natural cement in the days when Portland cement was an imported luxury. The efficient and high class of work then done was not due to a better grade of materials, but was due in great part to the pride mechanics took in their work. The foreman who had charge of the construction of the concrete anchorages at Rochester and Monaca was so particular with the sand and broken stone for the mix that it was a common occurrence for him to condemn materials furnished by the Contractor who employed him, he was just as particular about the men directly under him who mixed and placed concrete, as he was with the class of materials that went mto the work. This condition of affairs continued in this vicinity until the use of American made Portland cement crowded out imported Portland cement and supplanted the American made natural and Rosendale cements. In the use of natural cements, time had to be given for them to set and harden, it took just so long to get possession of the work, and there was nothing else expected, but when American made Portland cement at $2.08 and $2.14 per barrel took the place of Dickenhoff at $3.50 per barrel, equally as good for all practical purposes, and gave immediate possessin of the work, there was a complete change brought about in the construction of substructure work. The word was passed along the line to mix Portland cement mortar and concrete any old way as it was quickly discovered that it not only hardened in 24 hours, but got harder than the natural cement mixes. This led to a certain class of Contractors cutting their prices and finally there was a general cut in all classes of masonry, and by all Contractors.

It is interesting to cite two examples:

(a). The specifications for the river piers at Rochester-Monaca highway bridge called for Beaver sandstone, and the costing $1.25 per barrel, and two parts by measure of river sand.

following mixes for mortar and concrete:

Mortar. Mixed one quart by measure of Rosendale cement.

Concrete. Mixed one part by measure of Rosendale cement, two parts by measure of river sand and four parts by measure of broken stone.

These were contracted for in 1895, during hard times, at $9.50 per cubic yard, the timber grillage, stone shell and concrete center all figured in as yardage under one classification at $9.50.

(b). The river piers of the Port Perry bridge were built for the Union R. R. under railroad specifications, which were especially strict regarding the ashlar or stone facing for the shell of the piers, and called for the following mix:

Mortar. Mixed one part by measure of Vulcanite or Giant cement at $2.08 per barrel and three parts by measure of Allegheny River sand.

Concrete. Mixed one part by measure of cement as above specified, three parts by measure of Allegheny River sand, six parts by measure of broken stone and two parts by measure of very fine gravel.

The piers including excavation and removal of same were contracted for at $6.85 per cubic yard, measured as in the Rochester-Monaca bridge.

The great discrepancy in the cost price per cubic yard can not be explained by the difference of geographical location, for while the former was built 25 miles west of Pittsburgh with the channel pier on the Rochester side in only four feet of water, the pier on the Monaca side on dry land at extreme low water, and the freight on cement slightly higher, it must be remembered that the stone for the ashlar and concrete was quarried almost within sight of the bridge; while on the other hand six of the seven piers of the Port Perry bridge had the advantage of navigable water in their construction. Neither can the change of mixtures account for the difference.

The average price quoted for river masonry showed a reduction from 25 to 40 percent, in many cases ending in a loss to the Contractor. It resulted in a complete overhauling of the methods of construction and unfortunately introduced one requirement from the foreman and the time-keeper that has caused more annoyance and been directly accountable for more violations of specifications than all the other causes combined. It is not the necessity of reporting daily upon the amount of work

done, but the pernicious habit of rating a foreman according to the daily yardage he can show. If a foreman knows that his rating and pay with the Contractor who employs him depend upon the yardage, it can be depended upon that the yardage is somehow kept high, which means either slighting the work or abusing the Contractor's plant, and generally both. The inspection of river pier masonry construction today is more rigid than it was in the days of natural cement, yet, notwithstanding this additional care, the workmanship is with few exceptions inferior, and were it not for the fact that the quality of American Portland cement had reached such a high standard, the finished work would be retrograding rather than reflecting the care and thought given upon design, inspection and vastly superior foundations.

Although the Author has designed foundations within the 60-mile limit aggregating several hundred thousand cubic yards of concrete construction, no river pier has been constructed of solid concrete above low water or Pool Full line. This style of construction has not been cheaper than piers with stone shell and concrete core, and so long as the Beaver Valley and Mahoning sandstone give such excellent results a change to solid concrete construction is not called for, and should not be specified. The Beaver Valley sandstone does not crack, spall, or weather in place, in a river pier, while on the other hand the Author has not seen an all concrete pier that is free from cracks that time only can determine the amount of resultant damage. If the concrete pier was the cheaper the Engineer might be justified in substituting concrete for stone.

The argument has been made by certain advocates of reinforced concrete that a large quantity of yardage could be saved. In answer to that argument, it is interesting to refer to a certain bridge across the Monongahela River with a channel span of 517 ft. 6 in. center to center of channel piers. The piers were built so light that the expansion and contraction in the channel span rocks the pier on the expansion end, rocks two shore piers and has broken the third shore pier at the ground line; and, as a matter of fact, the expansion and con-

traction of the channel span takes place at this third pier, 559 ft. 6 in. away. This condition developed before the structure was completed, and was predicted by the Author. It could have been prevented by adding two more rows of piles and six feet of width to the base and footing courses of the channel piers as suggested by the Author. The piers, designed for a vertical load only, are so light and so weak sideways that the friction of a nest of six 4-inch rollers 2 ft. 3 in. long was actually sufficient to rock the channel pier and the two frail shore piers. A slight increase in yardage would have added needed weight and stability. There may be places where it is quite proper to save yardage; it was very unfortunate in this case.

The introduction of steel reinforcing has unfortunately been coupled with more or less mania to cut down the sectional amount of concrete. There are places such as floors of buildings, and members not exposed to the elements where such designing is good engineering. We all know that steel in inside construction acts vastly different in resisting the tendency to rusting from that exposed to the weather. My observation is absolutely the same with reinforced concrete construction, and for that reason the Author has continued to reinforce plain concrete work with steel where more strength is desired and to prevent cracking, but not with the studied intention of saving money at the expense of stability.

The tendency to figure the section down to the last fraction of an inch in thickness and lay stress of argument on steel that has an elastic limit of 65 000 lbs. per sq. in. is meeting with its just reward in principle as bad or worse than frenzied financing.

Like everything else that meets with success the best results reflect painstaking, and eternal vigilance is the price of good masonry and concrete work. Some of the best masonry work done has been that laid in zero weather for no other reason than that the Engineer in charge, the inspectors and Contractor knew that the greatest care must be exercised, the water, sand, gravel, or stone kept warm, and the finished work protected, which resulted in uniform, harmonious action all along

the line, and a uniformly excellent quality of finished work. It is wise to add about one quart of common salt per cubic yard of concrete in weather below 20 deg. fahr. and after 15 years of close observation no bad results have been detected in any stone masonry, concrete foundations, or concrete pedestals and walls where it has been used. Concrete work can freeze solid after it has taken its initial set and before hardening, thaw out in the spring and harden up without suffering any loss in strength, provided it has met with no shock, such as blasting, etc., during the hardening process. A stinging blow of an 8 to 10 lb. sledge on a block of concrete four by four by four feet. while hardening, has been known to ruin the work. Carelessness in erection on green concrete often does more damage than poor mixing, and instead of the efficiency being 85 to 90 percent, it is often reduced to 50 to 60 percent, where a little care exercised, or timely supervision, would pay many times over the cost of an experienced supervising engineer. There is far more damage done to concrete work from careless tramping over green work than freezing or even zero weather, and far more damage than both of these combined is done by permitting the green work to literally starve for water.

It is a rare exception that green concrete and mortar work get even a small fraction of the amount of water in actual construction, hardening and final seasoning, that is absolutely necessary for ordinarily good and much less for high class results. This starving for water is one of the greatest abuses in general use that is universally permitted.

During the process of setting of cement, sharp crystals are formed which in good work are so sharp they prick the palm of the hand like so many pins, thereby giving away the simplest secret in the detection of a poor mix. As all one has to do is to press the palm of the hand against the freshly hardened work; if the angles of crystalization prick the hand so it is painful, the work is good; if it is soft, the work is bad, a simple but severe test. These sharp crystals that prick the hand like the points of so many pins can only be formed by an abundance of pure water, hence the fatal mistake of starving the work

for want of water. This is just as necessary in laying ashlar with a ½ inch joint of mortar, as in concrete work. The Author had so much trouble in getting Contractors to wet the stone thoroughly that of late years specifications call for the Contractor to submerge in the river each stone just before setting, in weather other than freezing. By doing this all dust is washed off the stone, and it is thoroughly wet. If this were not done, especially in the summer time, the warm dry stone would absorb all the moisture from the mortar, retarding, if not completely arresting the chemical action and reducing the efficiency of the work anywhere from 20 to 30 points in this one item; one that the Engineers have been unpardonably careless in enforcing and often on that ignorance of has been clearly maifest. It is easy to blame everything on the designing Contractor, yet, in my experience, but one Contractor has failed to make good when placed on his honor and who deliberately set out to systematically slight the work. This remark must not be taken to mean that resident engineers and inspectors should not be placed on important work, and kept there day and night, the time will never come when both the company and the Contractor will not demand their inspection and assistance. The word assistance is used advisedly with full knowledge that the Contractor, and all the men employed by him are quick to detect the willingness of the Engineer and his assistants to assist the Contractor in the many little ways that can always be done in carrying on important work. It is within the power of the Engineer to interpret the specifications on any work in such a way that the Contractor may make or lose a good profit, and with no benefit to the construction. A Contractor is made of flesh and blood just as is an Engineer, is just as human, and is just as susceptible to decent treatment. Show me a successful Engineer who doesn't resent harsh treatment, and unfair decisions from those who may be over him. The Engineer in charge of construction who fails to appreciate his position as arbitrator on all questions of disputes between the Contractor and Company, and who feels called upon to interpret the plans and specifications always in favor of the company

who pays him, is dishonest, a coward and unworthy the title of Engineer.

With one exception the better the Author has treated the Contractor the better the finished work. Furthermore, when one Contractor gets stung others soon find it out. The Author has in mind several cases where the arbitrary ruling of an Engineer has resulted in the Contractors, by common consent, adding to their unit price to both sub and superstructures to such an extent that it amounted to an extra of over 10 percent in excess of what should, and would have, been bid for the same work constructed under fair treatment. All of which the Company paid in blissful ignorance.

You may feel from these remarks that the Author favors the Contractor. That is exactly the case within certain limitations. The Author spent 15 years of his life as a Contractor, and has consequently, been on both sides of the fence, and has paid for many of his own mistakes out of his own pocket, which helps to keep the memory fresh; and he still smarts when he recalls many of the rank decisions that have caused him needless loss of money, and to this day keen humiliation. Furthermore, the Contractor assumes all contingencies and should be liberally treated; he should be given the benefit of doubt. Do not expect more from a Contractor than you should from yourself, do not expect or ask him to shoulder your omissions and mistakes, unless you expect to secretly take care of him through dishonest estimates. Do not treat him as a rascal until he proves himself such. After he has proven himself a rascal, there is plenty of time to take him into camp. The Contractor is rare who doesn't respond to and reciprocate good treatment. First prove conclusively the trouble is with the Contractor and not his masons, it may be you are both deceived. The relations of the Engineer and the Contractor have been treated rather plainly for the reason that a large percentage of bad results should be charged direct to the Engineer and poor materials. A poor Contractor and a competent Engineer generally result in fairly good construction, but good materials, a good Contractor and an incompetent Engineer insures indifferent construction.

It would appear from what has been said that there wasn't much left for the helpless company after the Contractor and the Engineer get through with it, but to pay the bills and be thankful they were not greater. This is by no means the case, the company is responsible for the appointment of the Engineer in charge, for the loyal, or otherwise support given him, and too often the choice of the Contractor, who has only the merit of low bidder for his recommendation.

In days long gone by the Author assumed to know everything by intuition, certainly not from experience, and it was his habit to dictate to the Contractor how the work should be done. It is the province of the Engineer to see that the quality of materials and finished work comply with the plans and specifications, and in doing this the terms of the agreement have not been violated. It is unfair and contempible in the Engineer to insert any clause in an agreement compelling the Contractor to assume and stand good for unforeseen conditions, and contingencies, without just compensation that both the company and the Engineer did not and could not anticipate in the plans and specifications. Such a clause and such cowardly rulings will almost justify an honest Contractor slighting his work, it is only human for him to do so, and one should ask no more from the Contractor than should be expected from himself under similar circumstances and like treatment. It is so easy to unload on the Contractor with the full knowledge that the Contractor is rare who wishes to even dispute the rights of the Engineer for fear of bad treatment. In earlier days the Author presumed to be sole *arbitrator;* in other words, attorney, judge and jury, but some sense of the fitness and fairness of things, together with some mighty hard jolts shot that nonsense out of his head long ago.

It is the plain duty of the Engineer, if he has any ability, to see to it that the work done complies with the plans and specifications, and to that end decide all questions concerning quality of materials, workmanship and construction, but sacredly keep his hands off the management and direction of the work, and any and all disputes arising between the company

and the Contractor that do not effect the quality of the work done. For instance, the Engineer makes plans for a river pier with pile foundations, concrete base, stone shell and concrete core, constructed according to printed specifications. Does it make any difference to him whether the Contractor makes a double crib and back fill, or drives steel sheet piling, just so long as the finished work is completed according to plans and specifications? Does the Engineer presume to dictate to the Contractor how he shall manage his work, and then make the Contractor responsible for the mistakes of both the first and second parties without just compensation?

The Author knows of certain companies and engineers who think it smart to keep from contractors certain information, other than plans and specifications, that if known to contractors when bidding on work would materially change the price of construction, resulting later on in delays and loss of time and money. Any company or engineer who knows from past experience that difficulties will be in the way for the successful Contractor, and do not acquaint him of same before the tender for the work is made and contract entered into, is dishonest. Sooner or later they are sure to be found out and the word passed from one Contractor to another, with that absolute certainty of paying extra in the future for contingencies. The Engineer who takes pains to explain to the Contractor, not only the meaning of the plans and specifications but also all the features of the physical conditions reasonably sure to be met with at the site, uniformly obtains for his clients the lowest safe bid that would be paid for the work. Such conditions guarantee good work, the best of feelings and rapid construction, the trade mark of a *successful engineer*.

ACHIEVEMENTS IN RAILROADING

By A. Stucki*

Without exaggerating, we may say that this country has been made by the railroads. Not only has section after section been opened up by them, but after being populated, they carry the products to the markets thereby developing agriculture and inviting trade and last but not least, the railroads in themselves are the most influential factor in the final industrial development, owing to the enormous tonnage of steel used for rails, bridges, axles, wheels, steel cars and locomotives. Imagine, as another instance, the drop in the coal industry were the two hundred million dollars worth of this commodity no longer burned yearly by the locomotives of this country. It is for these reasons that I have chosen the above subject for this evening.

At the present we have in the United States 350 000 miles of track, 60 000 locomotives, 50 000 passenger cars and 2 000 000 freight cars. The weight of the locomotives in working order has increased from 75 000 lb., in 1870, to 300 000 lb., in 1911, the Mallet compounds weighing even 450 000 lb., and the tractive power naturally increased in the same proportion. The speed of passenger trains in 1870 was 30 mi. per hr., now, on the fastest trans-continental trains, an average speed of 55 mi. per hr. is not unusual, and short runs are often made at speeds of 70 mi. per hr. and over.

The capacity of the freight cars kept pace in this procession. In 1870, 20 000 lb. was the average, now 100 000 lb., is undoubtedly the standard, but the Monongahela Connecting Railroad Company, the pioneer in this direction, has for the last eight years used many cars of 200 000 lb. capacity and today

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there is a strong tendency on all roads to build new equipment heavier.

A passenger can now enjoy the comfort and the luxuries of a first class hotel while traveling from ocean to ocean, and freight cars are interchanged with any railroad so as to reach any part of the country without reloading, and repairs of the cars are taken care of just as soon as they appear to be necessary, no matter whether the road owns them or not. This way, the cars are kept up and are kept going so as to bring in revenue.

To facilitate such repairs as far as possible and to improve the efficiency and design of the most important parts, a great many details have been standardized, so that any road in the country is able to replace such parts on foreign cars without delay. Such uniformity of construction lessens the cost of manufacturing. Consider, for example, the equipment a wheel foundry would require if every railroad had its own special wheel. As it is now, one set of patterns and chills will answer in all cases and a limited number of stock wheels at a car repair shop will take care of all the different cars, home or foreign.

Is this not a wonderful achievement in a country of such magnitude? Does this not speak well for the many railroad companies involved in this one important task of transportation? Compare the conditions here with those existing in Europe where government ownership is prevalent and all arguments in favor of similar conditions on this side of the Atlantic will at once cease. Canada, undoubtedly, looks at it from the same point of view, at any rate, all Canadian roads, excepting one, are operated by private companies. This is the more significant since some roads were actually built by the government and all the others heavily subsidized, but in every case they were turned over to private corporations for operation.

In view of the fact that until recently there was no general government control, the question arises, How was it possible to unite the various roads into such a harmonious and effective working system, an example for all other nations, althought this country is the youngest of them all? Simply because every individual employee and official is putting forth his best efforts, knowing that he will be rewarded proportionately, and the rail-

road company as a whole combines these individual efforts into a working organization. That such a spirit must win out is not surprising and it certainly forms a sharp contrast to the contentedness of the average employee of a government railroad.

Another means to accomplish such harmonious results are the different railroad associations, among which the Master Car Builders Association is by far the most important. In this Association every railroad in the country of any note is represented. Here the rules of car interchange are decided upon and the different standards are adopted. Indeed, were it not for this Association an interchange of cars would be impossible. At the same time the operation of trains would be much more expensive and the first cost of the equipment, as already pointed out, much greater; in other words, this Association makes it possible to handle and transport the products of this country in an economical way so that the freight rates can be kept comparatively low and still yield the railroad companies a reasonable profit. This is still more gratifying since the wages paid to the employees are higher in the United States than in any other country.

With such spirit and organization we do not need to fear that American supremacy will be overshadowed, provided the Interstate Commerce Commission does not unnecessarily hamper enterprise. In the meantime, efforts to economize and to increase the comfort and safety of the traveling public are being pushed with undivided vigor. The testing departments are getting larger every day and it is surprising how simple many complicated questions appear after the subject has been fully studied and followed up with the proper tests. The term proper tests is used because so called practical results are not at all reliable if not corroborated and explained by the proper theory. Nor is a mere theoretical analysis to be depended upon, and, whenever possible, it should be followed up by practical tests in order that some features may not be overlooked. If practical results and sound reasoning, i. e., theory, check each other, we cannot be far wrong.

It is, of course, impossible to cover this subject fully in an address of this sort and no intention exist to do so but a few of

the more important or most interesting cases will be mentioned and briefly described.

Headlights. In view of the high speed at which many of the trains are now run, a powerful and reliable Headlight has become imperative. In Missouri "where you have to show them" it is required that a man 800 feet ahead can readily be distinguished. This is nicely accomplished by a ¾ foot per hour acetylene lamp. This light is steady and without a glittering or dazzling effect on those ahead. The electric light also is often used, and is in some cases required by law, and with it the rays can be thrown ahead several thousand feet. The dynamo for this purpose is driven by a small steam turbine mounted on the same shaft and located usually on top of the boiler directly in front of the cab. The whole arrangement is very compact in size and simple in construction. However, by far the greatest number of locomotives use oil lamps, burning about 150 degree oil.

Furnaces. A good boiler which produces steam freely and economically is possibly the most important detail of locomotives. It is now a proven fact that, in order to do away with smoke and to burn coal properly, it is necessary to admit heated air above the fuel bed. This gives the volatile gases of the coal a chance to burn and the Central of Georgia Railroad, which has changed two of their engines so as to take in additional air through a heated arch, used only 102 lb. of coal per 1000 ton miles against 152 lb. in the same locomotives without this arch.* For this reason the question of mechanical stokers is now being rigorously taken up.

Ash Pans. The ash pan has received a good deal of attention, not so much for its influence on proper combustion as for the importance of having an ash pan which can be emptied and cleaned with ease and without making it necessary to go under the engine. In fact, this requirement has now become a law and many designs have been brought out to comply with the letter of the law. Among others, the Atlantic Coast Line got up an extremely neat design wherein the hoppers and doors are

*See Railway Age Gazette August 5, 1910.

simply keyed to a bonnet projecting downward from the boiler. This not only enables a quick renewal of the ash pan but it makes it possible to use the same hopper on different locomotives by simply varying the bonnets to suit the different boilers. Such an arrangement not only facilitates repairs but it also cheapens the first cost as a large number of articles of the same design can be built cheaper than single parts. The doors swing completely clear of the door openings, allowing the contents to drop freely, even the doors themselves in swinging around are freed from all ashes. When closed, the flanges on the door form a tight joint with the ash pan so that no hot cinders can get out and set the ties on fire.

Tubes. Leaking of tubes is often found troublesome and engines are more frequently sent to the shop from this than from any other cause. Diligent investigation has led to the conclusion that rapid change in temperature is responsible for this: Changes in temperature of the gases of combustion outside and especially the changes due to the colder feed water inside the boiler. One western road has overcome these internal changes by entering the feed water in fine streams and directing them upwards against the top of the boiler so that the water gets thoroughly heated before it mixes with the water. This avoids cold, local currents and has overcome the nuisance of leaky flues to an astonishing degree.

Superheaters. Since superheated steam gives higher efficiency, this principle has recently been made use of on locomotives and, although there is little available space left, superheaters of various designs were placed in the smoke box and good results have been obtained. The steam in passing from the dome to the cylinders is superheated by hot gases which ordinarily escape through the stack at a higher temperature, which means a further utilization of heat, and besides that heat used in this way is even more effective than if used in producing saturated steam.

Brakes. Stopping a heavy passenger train running at a speed of about 70 mi. per hr. within 1 000 ft. is a record which is usually not fully appreciated and the innumerable tasks which

forced themselves upon the Westinghouse Air Brake Company during the last 40 years called for an almost unlimited resourcefulness and ingenuity. There are several other air brake companies which are also entitled to a great deal of credit but the above mentioned company having been the pioneer in this field, their equipment will be mentioned in a brief way.

As matters stand now on freight trains the automatic brake is used exclusively, i. e., each car carries its brake cylinder and its air reservoir and, in case the train breaks in two, the brakes are automatically applied. These reservoirs are charged from the engine through the train pipe and the control of application at each car is obtained by varying the pressure in the train pipe. If reduced, the brakes go on, if restored, the brakes release and the reservoir is re-charged. In order to reach the last cars of a long train quickly and in order to get a higher average pressure into the brake cylinder in case of emergency, a great reduction in the train pipe pressure will set the valves, called triple valves, so that the train pipe helps to fill the brake cylinder up to a certain point and by so doing, reduces its own pressure and consequently the reduction travels much quicker towards the rear of the train than would be the case if all the air would have to escape through an opening at the engine. This feature has been found to be so valuable that in order to meet the requirements of controlling the long trains of today it is now applied, to a certain extent, in ordinary service stops. The only difference is that the air in rushing from the train pipe into the brake cylinder is passing through a restricted opening. The *K* triple valve of the above mentioned company is of this construction.

On passenger cars safety is doubly important. The fact, that at high speeds the brake shoe pressure can be greater without sliding the wheels than with slow speeds, has been made use of in designing the high speed brake. Here a high braking pressure is first applied while the train is moving fast and as it slows down, the pressure in the brake cylinder is gradually allowed to escape through the opening of the high speed reducing valve. Of course, the system is based on the automatic principle all the way through.

With the cars still increasing in weight and moving at ever increasing speeds, another system has been developed whereby a large additional reservoir is placed under each car to be used only in emergency cases. The class *L* triple valve, used in this case has a by pass valve which is operated by a large reduction in the train pipe pressure, thereby allowing the air from the additional, or supplementary reservoir, to help the ordinary or auxiliary reservoir to fill the brake cylinder. In an ordinary or service application, this by pass valve is not moved and the air from the auxiliary reservoir and a restricted amount from the train pipe alone enter the brake cylinder. In order to be sure that the pressure in the brake cylinder does not exceed a predetermined amount, a safety valve of large capacity is also used. This is called the controlled system.

The locomotives of later designs are so equipped that they may be operated in unison with the automatic brakes used on all trains, or they may be operated independently from the train. In this latter case straight air is used as this affords the simplest and best means to graduate the braking pressure at a short range. A specially designed distributing valve allows but one system to be cut in at any one time. This equipment is commonly called the *E. T.* equipment.

Trucks and Wheels. Locomotives with a long rigid wheel base have plain driving tires on the intermediate drivers so as to be able to pass sharper curves and for the same reason the leading truck is made swinging, and the trailing axles are now often allowed to swing radially. These features prevent binding between the wheel flanges and the rails, prolongs the life of these parts and increases the tractive power of the locomotive.

Desiring to make the tractive power still more effective, many ways have been devised to secure better lubrication for car journals and one of the best methods advocated provides that the waste is easily resaturated, is pressed against the journal and is prevented from rotating with the axle.

Cast steel centers with rolled steel tires are now mostly used for driving wheels. On the cars, freight as well as passenger, the chilled, cast-iron wheel has given excellent service but as the equipment gets heavier and the speed greater, the

demand for safety increases also, and in view of all this the steel wheel is now being used to a considerable extent and the results obtained are very encouraging.

A train passing a curve slowly makes a squeaking noise caused by the wheels grinding against the rails and if the train passes at high speed the grinding action is still there although one cannot hear the noise. This is destructive practice as the wheels and rails grind each other and the locomotive has to furnish the power for it. To avoid these losses some roads are overcoming this friction at the locomotives by greasing the flanges of the driving wheels, with very good results.

The Wabash-Pittsburgh Terminal Railroad has given this matter careful consideration. On the West Side belt tracks, with their sharp curves, the driving wheel tires suffered greatly until it was found that the life of the tires could be tripled, or quadrupled, by oiling the flanges. Flange oilers have been tried for years but without much success until recently, when it was discovered that a heavy asphaltum oil conveyed from the cab to the wheel flanges by a jet of steam becomes sticky so that it can be applied to the flanges without spreading to the tread of the wheel. This road has since equipped many of their engines with this device and the saving effected is enormous, if you consider the cost of re-turning the tires, the expense of remounting the wheels, the loss in metal turned off the tread, the loss in revenue during the time the engine is standing in the shop, and lastly, the rails are saved as much as the tires.

On the cars similar wasteful practice exists as regards the wheel flanges and the rails as they grind on each other and the locomotives has to furnish the power for it. Here, the problem is more important, yet as there are a great many cars to one locomotive it is more easily solved. All that is necessary is to overcome the friction at the side bearings which is the principle cause of the trouble. This friction prevents the truck from swiveling freely while passing a curve, thereby pressing the wheel flanges hard against the rail, making grindstones out of them. Being aware of this, there is now hardly a railroad in the country which is not giving this matter consideration and

many have determined to use only such side bearings which will do away with all this harmful friction. In this way, the life of the wheels on traction cars has been doubled and on steam cars the large proportion of failures due to flange wear has been almost entirely done away with.

Couplers. The contour of the coupler, its kunckle, size, head and shank are all defined by a common standard and no deviation is allowable. At the same time it has to be automatic in its operations and has to stand the most severe tests in order to withstand the service on the road. This is getting more severe every year because the trains are getting longer, the cars heavier and the speed greater. Besides that, new features are constantly suggesting themselves and an up-to-date coupler is expected to incorporate them all. For instance, a coupler is now expected to have a kunckle throw so as to make it unnecessary for the trainmen to go between the cars in opening the knuckles. The lock-set, i. e., the arrangement to keep the locking pin in an uncoupling position until the cars are separated is now universally placed in the coupler head itself, and an anti-creeping feature to prevent the locking pin from jarring open has been found indispensible and this is also taken care of in the coupler head without changing the size or contour of the latter in the least.

Is there anywhere a better proof of real ingenuity of the American inventor, especially if you consider that several thousand patents have been granted for automatic car couplers alone? Is it not surprising that such an intricate device has been made to withstand the blows set up in service of 600 000 lb. and often more? Indeed, if the manufacturer of steel castings had not come to the rescue such wonderful results could not have been accomplished.

Draft Gears. The tail end of the coupler usually takes hold of the draft gear so that any sudden shock on the coupler, either pulling or buffing, acts on a resilient member before it reaches the car. The resilient member is a great study in itself. Springs lend themselves admirably to form cushions, but, as the recoil is always as great as the original shock, plain spring draft

gears, instead of simply yielding under a blow, set up a series of oscillations between the two adjoining cars which has a tendency to rack them to pieces.

To do away with such damaging vibrations the thought was conceived to assist the spring resistance with a certain amount of frictional resistance. This naturally increases the total resistance but when the spring recoils, the frictional resistance works against the action of the spring and it is up to the designer to see that the recoil is sufficiently reduced as to be harmless. On the other hand, he must watch equally as closely that there is some of the recoil left else the spring will stick and defeat the whole object of the draft gear. Blows as high as 400 000 lb. are taken care of in this way with scarcely any of the objectionable internal oscillations above mentioned.

Valve Gears. The driving axles increase steadily in size and as a result the eccentric straps of the Stephenson valve gear assume very unwieldy dimensions and the space between the engine and frame becomes very congested; in fact, there is hardly room for effective cross bracing. To overcome these difficulties the Walschaert valve gear is now often used on heavy equipment in place of the Stephenson gear.

The Walschaert is a radial gear and is located entirely outside the frame where it can easily be inspected. This fact also is responsible that no offset rocker arm is necessary. Unlike the Stephenson gear only one eccentric is used which controls the valve travel in all cases. The block, which travels in the link, (unlike the Stephenson link, which travels over the block) controls the lead of the valve and since this cross head motion is always constant, the lead, also, is always constant. Of late a number of pin-connected outside gears have been placed on the market which use no link at all, but as yet none of them are used to any extent. The Walschaert gear is a very old design, having been used in Europe since 1844 to a very large extent.

Steel Cars. Steel has taken the place of wood in a great many places. For passenger cars it is desirable to have a conveyance which does not splinter in a wreck, as a large part of

the loss of life in train wrecks is due to this cause. Steel cars in such a case may be distorted and twisted but not splintered. Furthermore, they are fireproof on the outside, so that the danger of catching fire from adjoining cars in a wreck is overcome. Steel can now be pressed, baked, and grained in a natural wood finish so that the interior of a passenger car finished in this way is as brilliant as any wood finish, but, as such a steel is very expensive, an ordinary pressed steel painted in a dull color is mostly resorted to. It looks nearly as well, at any rate it is just as effective in making the cars fireproof inside also, which is another important feature as the horrors of fire from lamps and stoves in wrecks have been made impossible. The problem of heating these cars, the question of sweating and of sound carrying are being closely followed, and, though no serious trouble has so far been experienced, these points are now closely watched and undoubtedly will be satisfactorily solved as time rolls on.

In the design of freight cars, steel has. during the last 15 years, forced itself to the front. More freight can be hauled for the same dead weight, making the revenue per train load greater. The life of a steel car is possibly three times as long as that of its wooden predecessor and it cannot be destroyed by fire (often the wooden equipment is burnt up to clear the tracks quickly after a wreck) or destroyed beyond the possibility of repairs, as the members can easily be heated and pushed back into their original positions and often wrecked steel cars are, with a very small expense, restored and made as good as new.

All these advantages mean a more economical equipment and are the main reasons why the steel freight car is the adopted standard of today. In the case of the passenger car the principle consideration in adopting steel is the safety and comfort of the passenger regardless of revenue.

Lighting. The lighting of cars is done either by oil, ordinary illuminating gas, Pintsch gas, carburetted gasoline vapor, electricity or acetylene. Ordinary gas makes a splendid light, especially if used in connection with Welsbach mantels and is very inexpensive.

The Pintsch gas gives a very brilliant, steady light and is almost exclusively used on lines where charging stations are located.

Gasoline absorbed by cotton wicking is vaporized and mixed with heated air which mixture gives also a very brilliant and at the same time inexpensive light.

Electricity, naturally, comes more and more to the front, and there are three systems in common use. In one case the dynamo is driven by a truck axle and any surplus current is used to charge storage batteries which are used when the train is not in motion. In another system the dynamo is located in the baggage car and is driven by a steam engine, or turbine. The third system consists of storage batteries exclusively which are charged at certain stations and kept in readiness to take the place of those which need recharging.

The electric light, no matter what source it comes from, is exceedingly well adapted for special locations. On parlor and sleeping cars each compartment has an individual light and of late even the upper berths are provided in the same way. Is there anything prettier than such a well lighted train gliding through space in a dark night?

Acetylene with its powerful, steady, quiet and inexpensive light has also been tried and no doubt it will more and more gain favor as we go along and as we learn to master its peculiarities.

Heating Systems. The trains are now usually heated by steam or hot water. The stove has outlived its usefulness and, when used, is locked so that in case of a wreck it cannot set the car on fire. When hot water is used as the heat distributing medium, the water is either heated by injecting steam into it at each car, getting an independent circuit at each car, or if the steam cannot be had at the car (for instance, a postal car, standing on a siding with the mail clerks busy assorting the mail, or in the case of a standing car where steam is not available) stoves are arranged to heat the water while passing through coils in the combustion chambers. These coils are often double, i. e., a small pipe extends the whole length inside of the water tube coil. Such a double coil can heat the water in

two ways, by heat from the stove or by steam passing through the inside coil.

A very effective way is to heat the water in so called steam jackets, in which case the apparatus on a car is usually cut up into three or more independent circuits.

If steam itself is used as a heat distributing medium, two systems have been tried, one in which, on the return pipe to the engine, a vacuum is established so that the steam with a low initial pressure passes through the whole train and returns to the tender, hence it is called return system. In severe weather the high pressure, or direct, system has been found more effective and is now principally used. Here we simply apply steam of sufficient pressure at the tender to fill all the radiators after which the condensation is drained off at each car as fast as it collects. With a thermometer, usually located in the center of each car, the brakeman has an excellent opportunity to keep an even temperature throughout the run. There are naturally a great many variations in the different systems but the underlying elements, as just enumerated, form the basis of them all.

On good trains, the air in a car is not only heated but is also replaced, i. e., the car is ventilated. This is especially important on through trains where the outside doors are seldom opened. It is also important since the window frames are made to fit very closely. Often the fresh air is taken in at the roof. A double hood with a self-setting flap is always ready to scoop it in, no matter in which direction the car runs. It then passes through a voluminous duct downward between the car floors and enters the car proper just below the heating coils so that it is heated in its ascent. A corresponding quantity of foul air is taken out at the roof or deck sash by specially designed ventilators.

Vestibules. The wide vestibule is more of a blessing that it appears at first sight. It makes the train of actually the same cross section throughout, improves its appearance and reduces the wind resistance considerably. For the passenger it adds comfort as it facilitates reaching the dining, smoking and library cars. In fact, the whole train is now at his disposal and

any possibility of danger from passing from car to car is eliminated.

In the beginning we pointed out that a traveler on a through train has all the luxuries of a first class hotel. Strictly first class meals served in the most elegant style at reasonable rates, barber shops, bath room, library with all the latest periodicals and the daily papers, public stenographer, telegraphic system and even telephone connection at the main stations, all these are items to make travel pleasant. Besides that, it enables the passenger to transact his usual business while he is speeding across the continent. Is there any wonder if the railroads in such service have to carry from 3 000 to 4 000 lb. of dead weight per traveler.

There is much attention being given to improvements in the road bed, and strides are being made to get a good, steel cross tie, a tie that will last. Here the most important point to be watched is to get a tie, which will hold the rails in place without depending on bolts alone. This item is very important and is sure to add a great deal to the safety of trains. Another point, equally as important, is a large bearing surface between rail and tie and between tie and ballast, and, last but not least, a tie should be tamped as readily as the present wooden tie and should grip the ballast laterally so as to keep the track in alignment. All these points have been very closely watched and steel ties are now being tried out, which incorporate these features very nicely.

The improvements in signalling the trains by block signals, pneumatic, electric, and otherwise have consumed millions of dollars and books could be filled with their description.

All this and hundreds of other improvements are being made to insure safety of the passenger and of the railroad property itself.

True to the name of this section, I have only touched on mechanical points, although the achievements in the other fields of railroading are just as great and require at least as much ingenuity and skill.

DISCUSSION

Mr. F. M. McNulty: We have in service 200 cars which were especially designed to carry 100 tons or 200 000 lb. Of this number there are 100 steel gondolas and 100 steel hopper cars. We have loaded the hopper cars up to 276 000 lb. in a test case. This load was placed over the doors and the ore was piled about three feet above the sides of the car. This test was made in order to find out the strength of the sides of the car, and I am pleased to state that the sides only spread $\frac{1}{8}$ of an inch under the load.

The journals on these cars are $5\frac{3}{4}$ by 10 inches and the axles are straight instead of tapered. We use the standard M. C. B. $5\frac{1}{2}$ by 10 inch journal box, the arch bar truck and a 750 lb. cast iron car wheel. We have not experienced any more trouble with the heavy cars than we have with the regular 50 ton car.

As these cars are only used in the yard service, and our speed limit is six miles per hour. I am unable to state just how they would act on a long haul.

Mr. Frank McCune: We had a number of experimental plate steel ties in the tracks of the Monongahela Connecting Railroad, during the year 1907 and part of 1908, for a period of eighteen months. These ties were known as the McCune Steel Tie, on which I hold a patent. They were of box girder shape eight feet in length, four inches in height, and eight inches in width. The edges of the bottom of this box shaped tie were separated one inch, as by that means we eliminated the metallic sound of the steel tie when located in the track. They had four projections on the bottom, each two inches long to keep the tie in solid position in the ballast. The most important feature is the depression in the top surface of the tie of $\frac{1}{2}$ inch, extending through the entire width of the top of the tie from one side to the other the proper distance from each end. This is to make a positive non-rail spreading shoulder on each tie.

These experimental ties were made out of steel plates $\frac{3}{16}$ inch in thickness, because we had to make them with hydraulic jacks, having no machinery at that time to form the ties. The regular service tie should be made of steel plates $\frac{5}{16}$ inch in thickness, and should be pressed cold. The experimental ties

made of $\frac{3}{16}$ inch plate steel, mentioned above were imperfect as on account of having to form them with hydraulic jacks, it was impossible to handle the regular size plates for service ties, and in order to get the ties in shape and put in regulation form, we were compelled to heat each of the plates from eight to ten times. This process of heating the plates, injured them to a very great extent, so when the experimental ties were finished, they were all burned, and the walls of the depression very thin, but in order to make a demonstration, we put them in one of our tracks, where we have the heaviest service of any railroad in the community, as we use a great many cars, the capacity of which are 100 tons and have many heavy locomotives.

These experimental ties were in perfect condition during the period of 18 months, and our reports show that not one cent was expended in the maintenance for that portion of track during the above mentioned time, but the ties were too light when we put them in, and began showing signs of breaking, and we took them out of the track, but they demonstrated that this tie is just what is needed, because it has the necessary resilience to act in unison with the wheels of the locomotives, and the trucks of cars in going around curves. It saves jarring to machinery, and hard service on wheel flanges. I am satisfied when we get heavy machinery that will press this tie cold from a plate $\frac{5}{16}$ inch in thickness, it will be a very desirable tie.

We have had a number of prominent engineers examine this tie, and they all express the same opinion, that it is the most perfect tie they have ever seen.

Mr. Martin Hokanson: I would like to ask Mr. McCune what shape he considers best for a steel tie.

Mr. Frank McCune: My experience is, that the box shape is the best for steel ties, because it gives the necessary resilience to avoid hard jarring on rolling stock and machinery.

It has been the experience of several people that the concrete and other very rigid ties, are hard on machinery and the flanges of car wheels, necessarily making a higher cost in repairs. It has also been demonstrated that it is impossible to bolt steel rails to a flat surface on steel ties and keep them in position

under the heavy strain of large locomotives and heavy cars as they are constructed at the present time.

Mr. Martin Hokanson: Experiments that have been carried on by the Steel Corporation have been with a modified *I* beam more than any other style. It is well known that in European practice, in Germany particularly, they are using several different sections of box shape and those box shapes are considered of different values, and they have come down to certain box types that they consider better than others. I would like to ask Mr. McCune whether they have been basing their experiments on experience of any other railroads, in Europe or elsewhere, or on other experiments they have carried on themselves at any time.

Mr. Frank McCune: This was entirely my own idea, I have had no other experience at all.

Mr. A. L. Hoerr: The subject is one in which we are all interested, of course but in which few have had detailed experience. I have had some knowledge of this steel tie business in an indirect way in the use in switching roads of the tie as manufactured by the Carnegie Steel Co. and have understood that in this use it is satisfactory. But that would not be a very definite indication if the tie were used in a standard high speed track. Some difficulties have developed with the connection of the rail to the tie, and new forms of attachment are being constantly devised and tried, and it is hoped that one will be found that will fill the bill. If any one here has any knowledge of the use of this tie, or any other forms of anything connected with the details of these cars and locomotives we would be very pleased to hear from them.

Mr. J. A. Gearhart: I have not been much interested in the steel tie proposition, I was more interested in the motive power and rolling stock end of it when I was with the railroad. I have heard the maintenance of way department refer to some troubles we did have with steel ties, and I know that at one time they were taking them all out of the curves on account of some troubles resulting in a very bad wreck.

But as regards the parts of the cars and the locomotives I have had some experience and I think Mr. Stucki has covered the matter very nicely. I agree with him that the solid side bearing will have to go and will have to be changed so as to save the wheels and the rails. I also believe in time that the Master Car Builders Association will change the contour of their coupler. I think it is the right standard of coupling but I do not think it is altogether the correct contour. I know the Pennsylvania Railroad has quite a few curves where cars will not couple with the standard couplers and it necessitates having an auxiliary coupling going around a good many of the curves.

Mr. P. S. Whitman: Mr. Stucki brought out one feature in his paper, the equipment of locomotives with automatic stokers, that is a matter of interest to every one who lives in Pittsburgh. We are all keen to find a method of abating the smoke nuisance. I would like to ask if he thinks it is possible to build a stoker for locomotives that will do away with smoke.

The Author: This is one of those cases where practice and sound reasoning will have to go hand in hand to accomplish results. I know a large railroad system that is pushing the question of stokers as fast as they can, and personally I am convinced that it will not be very long before we have an automatic stoker locomotive. Until then, no matter how good conditions you have for burning coal, while the door is open the smoke is there, and I know that the results so far obtained by this road are very encouraging.

Mr. R. C. Wood: Referring to the matter of stokers for locomotives. I noticed in the Railway Gazette some time ago the results of tests made on a locomotive on the Pennsylvania Lines. It gave tests for several different runs and gave tabulated results.

The Author: I did not know that these tests were published. I remember also another stoker I saw at Washington during the National Railway Congress but do not know what particular results have been obtained.

Mr. Martin Hokanson: It was mentioned that the tie as well as the connection must be elastic and the whole system

of the connection of the rails to the ballast must be elastic to take care of the truck and the vibration carried over to the car in a way that saves the material. I would like to hear some opinions in regard to this particular point. If we make the connection from the tie to the roadway out of material that is very compact, for instance that which is used now, crushed stone, and a steel tie is connected to the rail in the very best manner and made as solid as possible, it would have a more serious effect on the cars than in the case where wooden ties are used that can take up any shocks or vibration.

Of course there is very little experience, but I had opportunity during 1904 to study the question of ties in Europe and to talk with some of the leading men, among others Victor Hahn who is considered as the man who has developed the steel tie proposition in Europe. I gave an example in this way. Suppose we have a machine that is working and a nut is loose that brings the whole machine into vibration and in a short time this machine breaks in one way or another, due to the vibration. He considered the tie system something of the same nature. He said if we could tie up the steel tie with the rail, fixing the two masses together, we have an amplitude of vibration that is greater but the number of vibrations per unit will be smaller, and he considered it would have less influence on the wearing of the material that if there were a greater number of small vibrations in the material, I am convinced myself, although there have been protests against the steel tie claiming it would be very severe on the rolling stock, that this can be taken care of in the springs, etc., and it is particularly in regard to this point that I would like to hear from Mr. Stucki or some other of the gentlemen who are car designers, as to the possibilities of being able to take care of the shocks in a solid system of superstructure as against the present system of wooden ties.

The Author: Regarding whether the rail should be allowed to vibrate independently or whether it should be united with the tie in such a way so as to vibrate as a whole, we must remember that the blows are set up by the counterbalance of the

driving wheels, irregularities of the car wheels, lateral swaying of the cars, application of brakes, etc., which always originate above the rail, hence to my mind it is clear that if the rail is made to yield freely, the pressure between the wheels and rails due to the above mentioned blows are not so great as if the rail and tie could yield as a unit and, in the latter case, the destructive action of those internal and unavoidable vibrations would be greater.

The difference between the two systems is of course more pronounced as the weight of the tie increases and this is possibly part of the solution why a concrete tie has not been a success, because its great weight, solidly united with the rail, would not yield so readily, hence the blows are greater. The other reason, undoubtedly, lies in the nature of the concrete material itself, i. e., its inability to resist continuous hammering. A yielding support between the rail and concrete tie is undoubtedly an absolute necessity and in a steel tie, which by the way has surely a great future, a construction which provides flexibility in the tie itself, is superior to the rigid one. This in turn will enable us to have an absolutely tight fastening without the annoyance of being constantly rocked and shaken loose.

FIRE PROOF CONSTRUCTION

Emile G. Perrott*

"A burnt child dreads the fire." This expressive adage might be amended to read. "A burnt child dreads the fire, but a burnt nation remains almost as reckless as ever." By this I do not mean that there is no individual effort to build fire proof, but that the laws of the country deal too leniently with this subject.

The statistics concerning the loss from fire in the United States are appalling when compared with the losses in European countries, where the per capita loss for the year 1907 is only thirty-three cents, as compared with two dollars and fifty-one cents in this country. Possibly one cause for this is the fact that our country is comparatively new and the excessive growth of timber made it very easy to construct buildings cheaply, as compared with the older countries, where the principle of conservatism has been in force for centuries. To those of us who have had to deal with the growing scarcity of large timbers for girders of buildings of heavy construction such as the mill type, the advent of a substitute for wood for these buildings, which did not materially advance the cost has been heralded with delight.

Many of us can recall the uneasiness with which we have viewed the gradual decline in quality and size of timbers for the type of building I have just mentioned, and the satisfaction which became ours when the knowledge of the commercial possibilities of reinforced concrete became apparent.

It might be stated that there always has been, at least, within the last twenty-five years, the means to build substantial and fireproof buildings by using iron or steel beams, with brick

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or terra cotta fireproofing. While this is true, the disparity in cost between the two types made the use of the fireproof type less general, especially when timber was so plentiful.

Today, however, there is a marked tendency towards a higher standard of buildings for all uses. This, of course, is only natural, with the continual expansion of the country and the increase in the wealth of its citizens. Also the older a community grows the more deeply it becomes rooted in the soil, so to speak, hence the greater need of permanency in its structures. This is particularly noticable when comparing the cities of the East with those of the West. We find in all the large eastern cities a decided contrast, in permanency and stability of buildings in general, as compared with the newer western cities. The use of a brick veneer over a wood building, so common in the West, is entirely absent, and the eastern tendency to build permanently is very evident. I do not say that the West is not alive to this idea of permanency, for it is the West that is giving to reinforced concrete its impetus, that is making it the leading building material of the age, and I look forward to the time when our western cities will be in advance of the eastern ones for their structural ascendency.

Fireproofing may be viewed from two standpoints, both of which must be co-ordinated to secure the best possible immunity from fire.

We have, first, the use of non-combustible material, properly fireproofed, in the construction of a building, and secondly the construction of stairways, elevator shafts, light wells, etc., in such a manner as to prevent the spread of fire from one part of the building to another. Very often we hear of a very disastrous fire occurring in a so-called fireproof building, such as the Parker Building, of New York. Close investigation usually discloses the fact that while fireproof materials were used in the construction of the building, other very important essentials were neglected, such as open elevator or stair wells from one story to another, small openings through floors for dumbwaiters, lack of proper protection for window and door openings where exposed to a hazard from adjoining property, too large an undivided floor area, jeopardizing a larger amount of the con-

tents to a fire than is necessary, and thus making it more difficult to cope with. Dividing a building into fireproof units offers one of the best means of preventing the spread of fire, and gives opportunity to operate the remaining portion of a plant, should one portion or unit be temporarily disabled.

Of the most common fireproof materials used in building construction we have hard burnt brick, burnt hollow terra cotta, reinforced concrete, plaster of paris, and cement plaster on wire lath. The relative merits of the various materials depend largely upon the manner in which they are applied.

The committee of engineers appointed by The American Society of Civil Engineers to report on the value of the various fireproofing materials used in buildings that were in the San Francisco conflagration makes the following statement regarding the value of brick, concrete, and terra cotta.

"For columns, the fireproofing that will stand up best is red brick set in Portland cement mortar. Equal to this is a casing of solid concrete at least four inches thick with a mesh of reinforcing metal."

Speaking of the collapse of buildings due to column failures, the report goes on to say: "The remaining examples of column failures must be laid to the failure of terra cotta tile. * * * The writers believe, however, that it is the least valuable of all materials commonly used for fireproofing.

For floor construction, some form of reinforced concrete is far preferable to tile."

The very thorough and complete series of experiments made by the United States Geological Survey show the relative fire-resisting merits of the various building materials, not only of brick, terra cotta, and concrete, but also of the various kinds of stone, such as sand stone, granite, marble, and lime stone.

A perusal of the report shows that the best fire-resisting material is hydraulic pressed brick laid in cement mortar. The various stones cracked and broke into small pieces. Terra cotta tile likewise suffered serious damage from cracking and falling off of the faces. Solid concrete blocks of various aggregates and mixtures showed that the concrete made with a

granite aggregate behaved the best, being washed and pitted from the surface to a depth of not more than 1½ inches in any case, while the sudden rise of temperature of the face of the panel caused the concrete to crack. This plainly shows the necessity of reinforcing all concrete used as fireproofing.

One phase of fireproof construction which is gaining some headway throughout the country is the construction of cheap suburban houses with walls of hollow tile finished in stucco,

Fig. 1. Fireproof Building with Outside Fireproof Stair Tower.

or of concrete blocks. The writer has built such houses, having obtained bids for ordinary frame houses and also for six inch hollow tile and stucco from the same plans, and finds that the tile house cost him in the neighborhood of $5,600.00; the excess cost of making the walls of non-combustible hollow tile and stucco being only $300.00. This is about 5⅓ percent of the total cost. When the superiority of this form of construction is considered and the saving of painting the wood work, which would be necessitated if the house were finished with clap-boards or shingles, the additional cost really amounts to nothing. The

deterioration, of course, is very much less, and the fireproof feature of the building makes it more than desirable when the house is built outside of districts where fire protection exists. If it is still desired to go a step farther and make the entire house fireproof, floors can be built of concrete joists with hollow tile fillers between, making level ceilings. Instead of hollow tile filler blocks, hollow plaster blocks may be used, if desired, the concrete joist being considered the carrying member of the floor. There is also another system with light floor construction in which a reinforcing mesh is placed underneath a row of tile acting as a compression member of the floor. This is known as the Johnson system.

It has been demonstrated that partitions of terra cotta tile for the smaller class of buildings, such as residences, can be used for carrying the floor loads without any additional stiffening, in the form of structural steel or other supports. It is surprising that this material has not come into greater use.

In considering the planning of a building, from a fireproof standpoint, no better arrangement can be obtained than that prescribed by the Fire Underwriters. These requirements of course vary according to the occupancy, but briefly stated, embody the following points:

All stairways and elevators must be enclosed in a shaft built of fireproof materials, with fire doors to protect the openings.

No openings to occur between one floor and another without some means of closing in case of fire.

Large floor areas to be divided by fire walls with automatic fire doors to protect the openings.

Metal frames and wire glass, or fire shutter, to protect window openings occurring on a narrow street where fire hazard is great, fire walls to extend at least three feet above the roof in buildings not fireproof.

Automatic sprinklers to be installed in all buildings whose contents are combustible, even if the building is fireproof.

Looking at these recommendations it does not seem that they are difficult to follow. Of course, some modifications must be made to suit buildings of different occupancy; for instance, an

office building does not need fire walls to divide up the floor area, as each individual office becomes such a unit. A department store, however, should be so divided, and every precaution taken to isolate one department from another. The new Wanamaker store in Philadelphia is an instance of this.

Fig. 2. Fireproof Building with Inside Fireproof Stairway.

There is no reason, however, why stair and elevator walls in fireproof buildings should not be enclosed in transparent enclosures, such as an ornamental iron framework with wire glass, either polished or rough.

The new cabinet factory of the Victor Talking Machine Company, Camden, N. J., shown in Fig. 1, is an excellent type of fireproof building from all standpoints. There are no unprotected openings through the floors of the building. All windows have metal frames and wire glass. All stair and elevator shafts are on the outside of the building except one, and

all are enclosed in brick walls with fire doors made to close automatically in the event of fire in the case of the elevators. Open fireproof balconies form the means of access from each floor to the fireproof stair towers. These towers are required by the laws of Pennsylvania in all cities of the first class, and are the fire escapes of the building. The superiority of this type of fire escape over the ordinary outside balcony and ladder type has prompted us to use this fire escape in other cities,

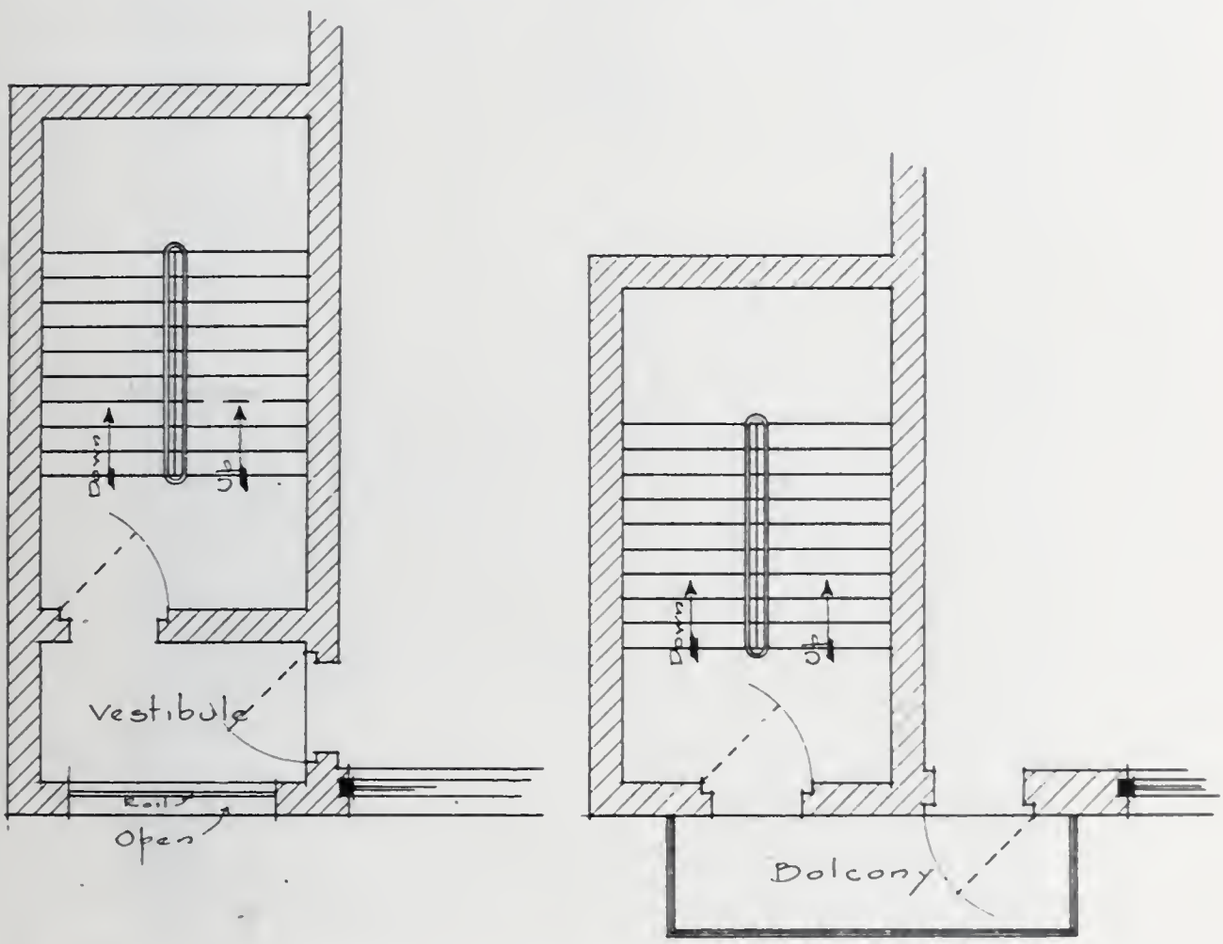

Fig. 3. Vestibule and Balcony Types of Fire Towers.

even though not required by law. A brief description here is in order. There are two methods of building the approaches to these fireproof towers, one being the use of an outside balcony as shown in the illustration; the other being a fireproof vestibule within the limits of the building, shown in Fig. 2. This latter type is usually employed in the more ornamental class of buildings. Both arrangements require fireproof doors on the opening leading from the floor to the balcony or vestibule and on the door opening into the stair tower. All windows in

the stair tower should have metal frames and wire glass, and if not made stationary should close automatically in case of fire. The vestibule and balcony types of fire towers are shown in plan in Fig. 3.

Fig. 4. Fireproofed Steel Tower.

The stairs themselves should be of fireproof material, either cast iron or reinforced concrete. Where the story height of the building is sufficient, say 14 feet six inches, or more to the top, it is possible to get two sets of stair in the one shaft, making what is known as a "Scissor" stairs or "Double Threaded" stairs. Each stairway is entirely separate from the other, and by reaon of this fact lends itself admirably to the use of schools, permitting the two sexes to use the same stair-shaft without intermingling on the stairs.

The large steel sprinkler tank and tower, shown in Fig. 4, is an instance of the beneficial result derived from the use of concrete from an insurance standpoint.

This tank holds 100 000 gallons of water, the bottom of which is 125 feet from the ground. The total height of tank and tower is 174 feet. The diameter of the tank is 20 feet. The tower is erected on filled ground near a river and the foundations of the four legs are supported on concrete piles.

By reason of the close proximity of buildings belonging to other owners, the company desired to take out Indemnity Insurance on the structure as originally designed, that is, without any concrete protection, so that in case of a fire in the buildings adjacent and the collapse of the tower, the damage to adjoining property would be covered. This, they were informed, would cost $500 per annum. It was finally decided not to put any insurance on the structure, but instead, invest about $4000 in fireproofing the tower with concrete. A little reflection will show that the investment fully pays for itself, not only financially, but by practically making the tower immune from fire and the destructive agencies of the atmosphere, which would not be the case if left unprotected. If we charge against the tower the interest on $4000 at six percent per annum, we have $240 as the carrying charge for the absolute protection against fire, instead of a $500 charge for no absolute protection to person or property, but simply to cover any damages for which the company might be liable in case of a collapse of the tower.

This clearly shows how it pays to carry your own insurance, so to speak, by taking precautions to avoid damage to persons or property by making a building fireproof. Further, the saving on the insurance premium will pay for the fireproofing in about 15 years, so that at the end of that time the original cost of the fireproofing will be wiped out. This, of course, is based on the assumption that insurance would be carried on the tower if it were not fireproofed.

DISCUSSION

Mr. Morris Knowles: As I listened to Mr. Perrot's account of the report of the Committee of Engineers relative to the behavior of certain materials during the San Francisco fire, I could not help but be impressed with the necessity of intelligent, fair and impartial requirements in a "Building Code." This is all the more strongly brought to mind, when we remember the recent agitation of about a year and a half ago, in New York City; where, to say the least, it seemed as if the requirements of such a code were determined more upon the influence of proprietary interests than upon the broad and fair interpretation of the qualifications of different materials and types of construction.

This is a subject in which the Engineers' Society, particularly, as well as all other public organizations, can well have an important influence with those who have the duty of framing a "Building Code." Those who attempt to draft such regulations should be broad minded, with clear thoughts and of strong character and be fair to all interests. The subject is complex and involves many different things besides the pure strength and fire resisting qualities of materials, although these may be the most important; but, in addition to these, many other matters, like sanitary provisions and spacing between buildings, which commonly come under tenement house laws and similar health regulations, all should be combined in any such code.

Definite and exact requirements will, of course, increase the cost of building, but, as they cause unscrupulous and reckless builders to do better, are certainly a step in advance for the public good. The most important criterion is, however, that the drafting of any such code should be entirely free from the influence of proprietary interests and should permit the use of any and all of the very best materials for the purpose in mind. The cost of construction should not be made unreasonable, that the maximum of safety, convenience and health for the people may be secured with the least burden of expense.

The Engineers' Society is composed of men who know, from their experience, what can be accomplished and they

should therefore use their influence, in season and out of season, to bring about the broadest consideration of such requirements in the city.

Mr. W. A. Weldin: I was very much interested in the views showing fireproofing of steel towers. I would like to ask the Author if he can give us an idea of the cost of this kind of work per lineal foot.

The Author: That particular tower in question cost $4000 to fireproof. It was done by contract. We were the designers and the contractors were a Philadelphia firm who bid on the work in connection with several others. I did not take off the costs on a foot basis. But there are four legs 135 ft. long and a spread of about 22 ft., the parallel struts are about 20 ft. apart. To reduce the cost to a yard price would not be a good basis because the labor cost is the largest item. You could reduce it to a lineal foot price which I should think would be more satisfactory, on this basis the cost is $3 per lineal foot of fireproofing.

Mr. Samuel E. Duff: In connection with this tower I would like to ask whether any crack in the concrete was noticed due to the deflection of the steel work.

The Author: I looked at it the other day and I could not find any. We have some pretty stiff blows in that vicinity. A few weeks ago it blew a man off the roof of an adjoining building and he was killed, but I could not find any cracks as a consequence of the high wind.

Mr. Samuel E. Duff: That is surprising. I would expect some cracks from the action of heat and cold on the different sides of the tower without considering the action of the wind. I would like to ask whether the gentleman is sure no cracks occurred. If we find no crack in that tower I think we have found that concrete is elastic.

The Author: If there were any cracks in the tower the concrete would remain in position because it is reinforced to accomplish that result. It would be inadvisable to put fireproofing around any structural member unless there were means

employed to hold it there when the temperature changes. There may be cracks now. I did not examine it at the top, but I examined it as far as I could see from the sidewalk by getting close up to it. There do not appear to be any cracks, and if there were I would not be afraid of them. We have built concrete chimneys which have cracked and there has been no trouble from them. I have in mind two which we built, one of them being very badly cracked, but it does not seem to be seriously affected. The only bad effect that could be produced is by the sulphurous gases getting through the cracks and attacking the steel reinforcement. But if the cracks were that serious they could be grouted up with cement.

Mr. Samuel E. Duff: That is the point I was getting at, the possibility of cracks allowing moisture to get into the column. Such a thing would not be noticable and yet might be disastrous. So I wanted to know if cracks had appeared. I think that is the principal criticism anybody could make of that construction. There is no question about the fireproofing effect of the concrete and very little question of the protection it affords the steel unless it cracks in such a way and at such places as will permit the moisture to get at the steel and cause corrosion which could not be seen.

The Author: I might answer that in general by stating that in every reinforced concrete building you have that same feature, and it is one of the objections some engineers make to reinforced concrete, if it cracks it permits the moisture to get in to the steel and rust it. However, I am willing to take my chances. Taking everything into consideration it is about as immune from collapse on that account as anything else. We demolished a building recently that was built four years ago and was subject to the most trying conditions, over boiler rooms where gases were continually coming in contact with the concrete and where some concrete had actually cracked. It took dynamite to get the building down and so much blasting was necessary that the city authorities stopped it for fear of damaging other properties, and after we got it down to the ground it was a question of breaking it up into smaller lumps for handling.

Mr. J. A. Ferguson: I would like to ask whether the speaker has any data relative to the fireproofing of buildings with hollow tile as compared with reinforced concrete in resistance to the action of heat.

The Author: I might answer that question by referring to the report of the U. S. Geological Survey on the San Francisco fire. All the steel frame buildings we have obtained bids on, fireproofed with terra cotta, cost more than that same building of reinforced concrete. Hollow tile fireproofing is not good unless it is anchored. I know of one building in Philadelphia that was so badly fireproofed with hollow tile that the underwriters at first refused to accept the building. It is commonly known that crevices very frequently occur in terra cotta fireproofing, and anyone that saw the results of the conflagrations in San Francisco, or Baltimore, knows that the hollow tile did not stand the heat on the bottom being spalled off due to the unequal expansion of the flat horizontal surfaces as compared with the web. Further there is more or less expansion of the air in the tile itself which forms pressure, and I was in a number of buildings after the Baltimore fire in which the fireproofing was practically destroyed, due to the fact that the tile had been broken from the actual heat or expansion of the air in it. The report of the U. S. Geological Survey above mentioned shows a number of instances where the fireproofing fell off columns and the columns in consequence were squashed down so they bulged out like a barrel.

Mr. J. A. Ferguson: Usually people in speaking about a hollow tile fireproof building indicate that the hollow tile is fireproof, that it will not conduct heat; but it seems to me the air is a non-conductor at low temperatures but at very high temperatures such as at a fire the air is pretty nearly as good a conductor of heat as steam, which is very good. Am I right or wrong in that?

The Author: I could not answer that question. But I might state that if the workmanship is good there is no reason why hollow tile fireproofing, if properly constructed, should not be good. There is no reason why a steel frame building with hollow tile, fireproofed, should not be equally as good as any

type if the material is thick enough to resist the stresses due to the expansion and contractions, and is properly anchored.

Mr. J. A. Ferguson: I have heard that the air in hollow tile construction is a good conductor at high temperatures. Is this generally conceded to be true?

The Author: I do not know, but I know that the exposed faces of tile split off, due to the expansion. Whether it was the air or the expansion of the outer surface and cracking off from the webs I do not know, but I think it might be a combination of these causes.

Mr. V. R. Covell: What was your statement in regard to the minimum thickness of concrete over steel?

The Author: For important members like columns, a minimum thickness of three inches, for ordinary beams two inches on the bottom and 1½ in. on the sides. On the steel tank we used three inches on all the columns and struts.

Another thing about fireproofing, it should be rich a 1:2:4 mixture, not any leaner than that. Another thing of importance is the character of the aggregate; a soft limestone not being good for fireproofing. It will disintegrate under the action of water when it is red hot, just as quick lime does, so it is necessary to have an aggregate that is more or less refractory in its nature.

Mr. A. F. Link: Do you think on a 28 foot span an 18 inch I-beam, 60 or 65 pounds, enclosed solidly with concrete two inches thick would be ample fire protection for that size, in case of a hot fire, and would that need any mesh wrapping before the concrete was poured around it?

The Author: I will answer the last question first. I would say you could not fireproof properly with concrete unless you reinforce it. I have seen concrete drop off a beam without a fire, due to the contraction. On a 26 ft. span I would not hesitate to put two inches of concrete, we do it very frequently. My theory of constructing buildings is simply this, that the more incombustible you make a building the less there is to burn. If you make the regulations too severe it will put the price of fireproofing buildings too high, and will limit the num-

ber of fireproofed buildings built. It is much better to have an incombustible building which is fireproof from the ordinary standpoint, not necessarily conflagration fireproof than buildings with wood floor construction. I have seen a floor supported by steel beams with the flanges exposed and brick jack arches between, survive a fire unharmed. The fire never got headway enough, due to the lack of inflammable content, to make it hot enough to injure those beams. But a floor of that description would not stand a four hours fire test at 1700 deg.

Mr. R. B. Woodworth: What do you say to the idea that one of the advantages of hollow tile in fireproof construction is that it has already been through the fire, and one of the disadvantages of concrete is that it has not?

The Author: I simply answer that statement by saying that hollow tile depends for its monolithic effect on the cement mortar that is used in the joints, and that cement mortar used in the joints is practically the same as concrete. If your hollow tile is all right and your joints are not your fireproofing is not good.

But the proof of the pudding is in the eating. The one example I showed you of the fire test by Prof. Wilson, is only one out of about a hundred he has made. He usually makes them in New York in a building the walls of which are of concrete. I do not know how many fire tests have been made in the house. At the time I spoke to him he told me it had gone through about four fires without serious damage. The brick walls of the test house I showed were badly cracked and spalled by the heat and water.

Mr. Samuel E. Duff: You spoke about the cost of the steel frame terra cotta fireproofed building in comparison with concrete. As I remember, most of your pictures were buildings which did not require very expensive finish. I would like to know about where the line of demarcation is. When does it pay to use steel frame and terra cotta fireproofing? Supposing it to be built perfectly, what type of building, or how elaborately finished a building, would it be where you have to stop using concrete? I think it is true that certain types of building are

not economical to build of reinforced concrete because the finish is too expensive.

THE AUTHOR: In regard to the cost or the point where the reinforced concrete ceases to be economical and a steel frame with terra cotta fireproofing becomes economical, I cannot tell you anything definite, except this: In the case of a hospital we built, which required good finish and was rather intricate, we obtained bids both on reinforced concrete and steel construction, and found that the reinforced concrete was not any more expensive than steel frame fireproofed. Further, I do not think the gentleman is right in regard to his idea of finish being more expensive in a concrete than in a steel frame building fireproofed with terra cotta, for this reason. A concrete building as I understand it, simply means the cage, that is the vertical elements and the floor systems. That cage has to be made so as to carry certain loads. And if you prefer level ceilings it is just as easy to get this effect without adding to the expense with reinforced concrete as it is to have the beams show. We are building a group of buildings costing about $300 000, in which all the floors are reinforced concrete and the ceilings level. We are not using any false ceilings, but are using combination concrete joists with plaster block filler between and a two inch slab over the joints, the joists being on 16 in. centers and are four by twelve inches, reinforced by a rod and span 20 ft. The floor has been tested and carried double the live load on a 20 ft. span with only $\frac{1}{16}$-in. deflection.

MR. V. R. COVELL: What are the practical economic limits in height in reinforced concrete, of the type of building we are in?

THE AUTHOR: A type of building such as this would not be economical if built entirely of reinforced concrete. The structural cage, such as columns and main girders, should be structural steel and sufficient bracing members should be introduced for erection purposes. But there is no reason why the floor system between girders should not be reinforced concrete. We have in Philadelphia a large building in which that is done. The cage was put up of structural steel and the inter-

mediate beams and slabs between the girders are of reinforced concrete and all the fireproofing is concrete.

PROF. S. L. GOODALE: There is a question that may not be inappropriate here: Is concrete that is put up in freezing weather as satisfactory as that which is put up in warm weather?

THE AUTHOR: A number of buildings have been built in very cold climates and do not seem to have suffered very much by reason of that fact. What does injure concrete, from the freezing standpoint, is the alternating freezing and thawing, not a continued hard frost. If you put in concrete today and the temperature drops to zero and stays below 32 deg. for say two months until spring comes and you leave the forms in for several weeks after that time until the concrete gets its final set, the floors will be all right. But if you have a hard frost when you place concrete and it freezes, and then gets warm and before it has time to set, it freezes again, your concrete will play tricks with you. Our experience has been that concrete which is once frozen is all right if it is let alone and does not thaw and freeze a number of times. We had a building where there was a continual thawing and freezing going on and it did injure a floor slab so that it weakened badly. We made a test and found it was not up to the standard. In using concrete in freezing weather means should be adopted to artificially heat the concrete to keep it from freezing.

MR. E. W. BARTHBERGER: What is the relative fireproofing value of cinder concrete and concrete made of gravel or other aggregate.

THE AUTHOR: It is the best known fireproofing there is, but from the standpoint of strength it is very inferior to the stone concrete. Another point, you do not always get cinder concrete, you often get a great many other things besides cinders. It is unknown quantity.

MR. A. F. LINK: What is your opinion of good furnace slag?

THE AUTHOR: I would not build a reinforced concrete

building of slag or cinder. I would use slag for fireproofing provided it was old and not too green.

Mr. A. F. Link: I consider good slag for concrete equal to good cinders for floor and reinforcement work, but would not use it for column or girder work. The material above referred to makes a good concrete, light and durable, and where I have used it have found it to give perfect satisfaction when used with the same care that cinders are used.

EFFICIENCY OF ROPE DRIVES

By W. Trinks*

Power generation and power transmission are deservedly considered among the most important branches of mechanical engineering. The present paper deals with one branch of power transmission, namely that of transmission by hemp ropes.

The publication of a paper on this subject at the present time has been partly prompted by the rather general adoption of direct electric driving even in places where in the writer's opinion rope driving would have been better. It should be noted here that electric power transmission is to the mechanical engineer only one of the many forms of power transmission and is comparable to pneumatic, hydraulic, belt, rope, shaft, or gear transmission. But the comparison soon reveals the fact that electrical transmission possesses three points of advantage:

First. Convenience, efficiency and low cost of power transmission for long distances.

Second. Ease of power transmission to moving or movable objects.

Third. Convenience and accuracy of measurement of power transmitted and of losses (this is true only for almost constant loads unless special instruments are provided). The application of the measuring instrument is simple.

The advantages named under the first and second points have secured to electrical transmission a field of its own.

As a result of the advantages cited under the third heading, efficiencies of electrical transmission are well known.

How different in rope drives. Measurement of efficiencies of rope drives in commercial establishments is out of the question, because the cost of the necessary apparatus is prohibitive,

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and because its installation after the building of the drive is almost equivalent to an entire reconstruction.

We are therefore compelled to resort for the determination of such efficiencies to laboratory tests. The equipment required to make them on a scale which renders the results of commercial value is very expensive. The carrying out of the experimental investigations is still more costly and requires much time.

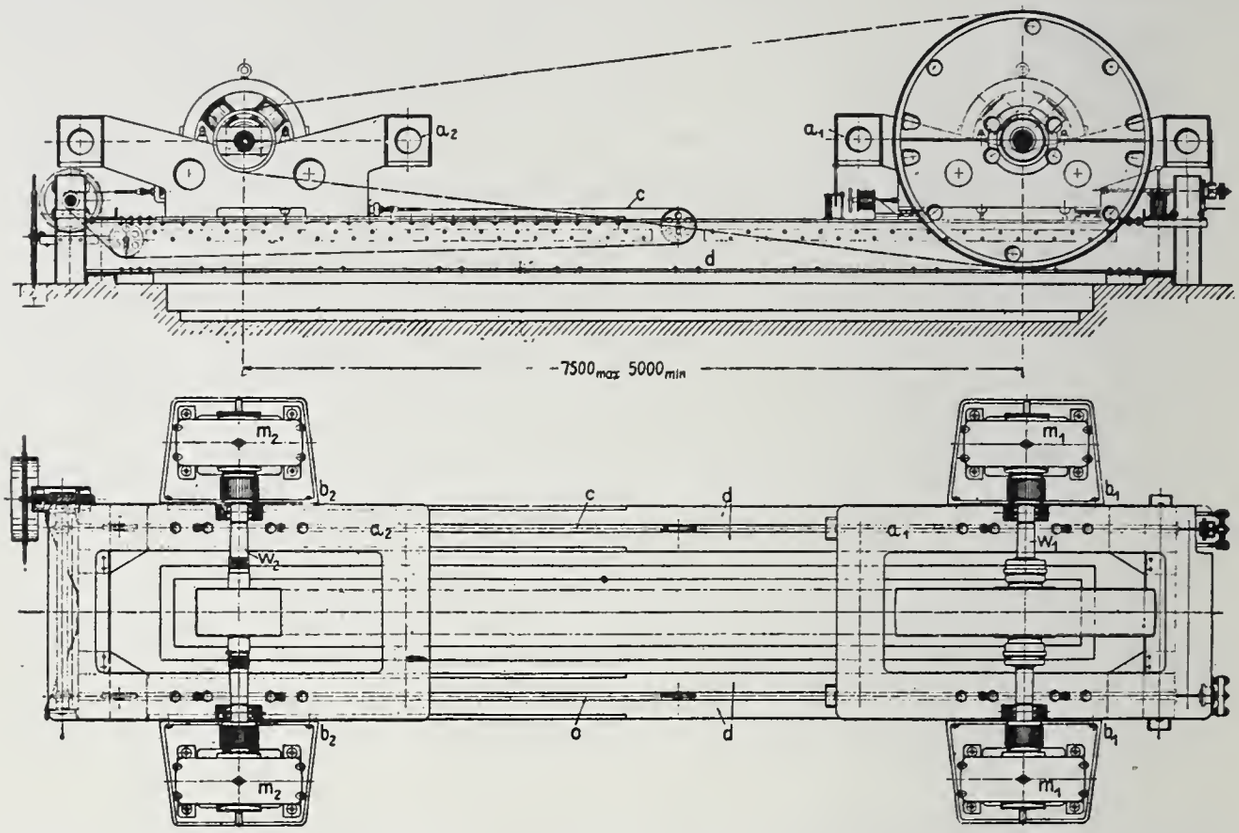

Fig. 1. Testing Machine at the Siemens Schuckert Works. (Now at Charlottenburg Technical School.)

The writer is in a position to offer two sets of experiments to this Society. One made in the mechanical engineering laboratory of the Carnegie Technical Schools and one made in a special laboratory of a factory (Siemens-Schuckert) in Charlottenburg, Germany. It will easily be seen that the Charlottenburg tests were much more complete than the Carnegie Technical Schools tests, but they were made at the expense of the Society of German Engineers and of prominent German manufacturers, whereas the latter were made by students in the regular laboratory work under the direct supervision of Professor J. C. Sproull.

A glance at Fig. 1 will give a slight idea of the German testing outfit. Power input and power output were measured by carefully calibrated electric motors and dynamos. (See appendix). Belt and rope pull and the influence of centrifugal force were measured by a hydraulic support of the "Emery"

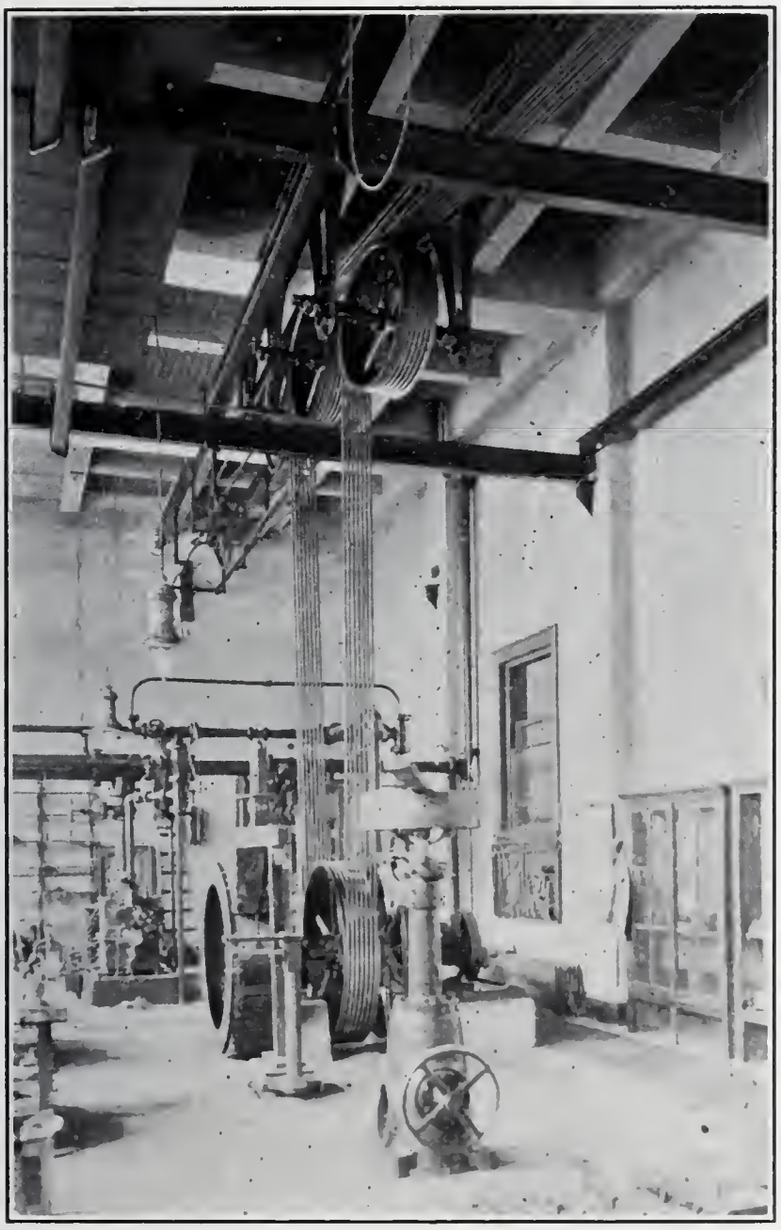

Fig. 2. Rope Drive in Carnegie Technical Schools.

type. Power up to 200 h. p. could be transmitted by the outfit. Tests were made both with the so-called English system of rope driving, independent ropes in parallel, and with the so-called American System, one continuous rope.

Figures 2, 3, and 4 give an idea of the Carnegie Technical Schools rope drive. A steam engine of approximately 100 h. p.

capacity drives a line shaft through a double turn continuous rope drive. Power input and power output were measured with a Prony brake as described in the appendix to this paper. The force exerted by the ropes on the bearings could not be measured, because the whole system is fastened rigidly.

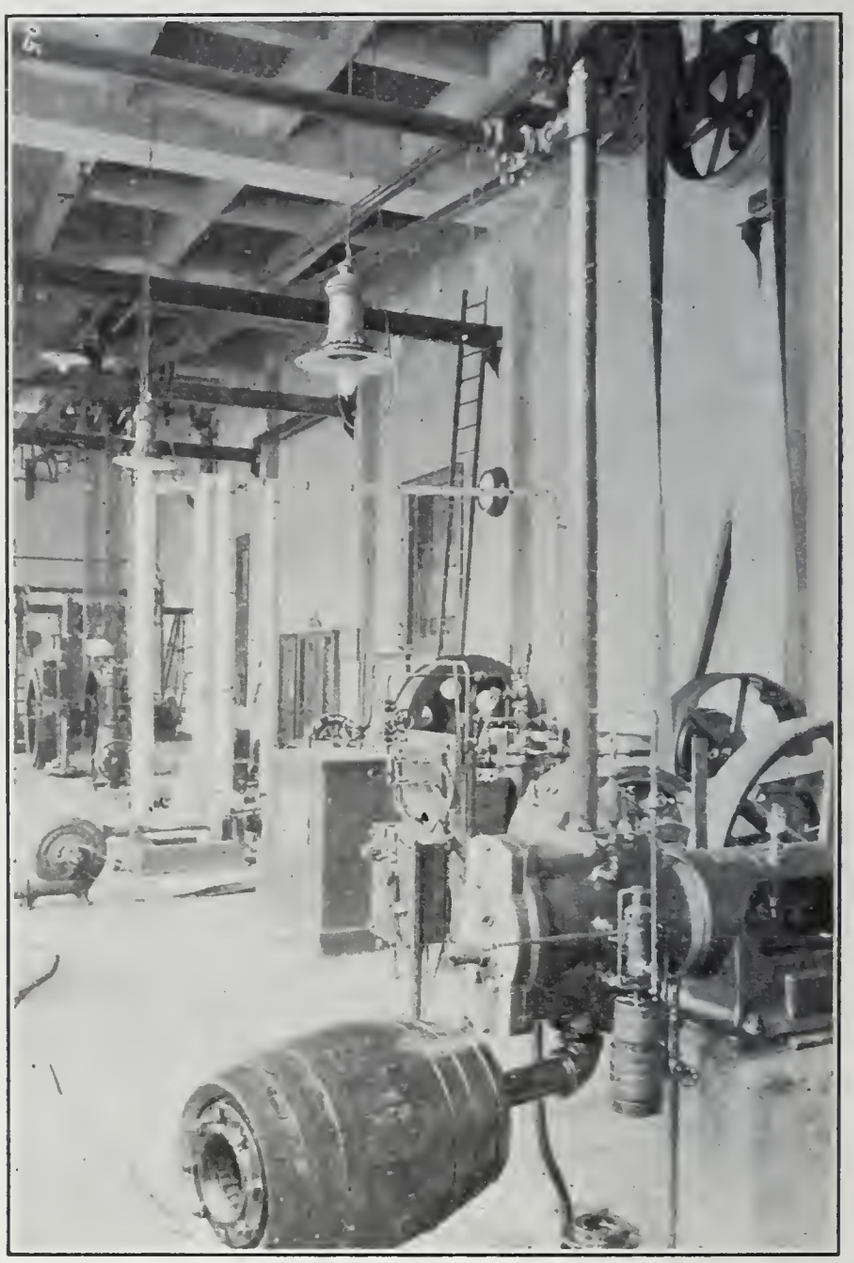

Fig. 3. Rope Drive in Carnegie Technical Schools.

The tension of the slack rope was maintained constant by exerting a constant force of 356 lb. on the tension carriage. Details for measuring methods for both sets of tests are given in the appendix.

Being convinced that the engineer is first interested in re-

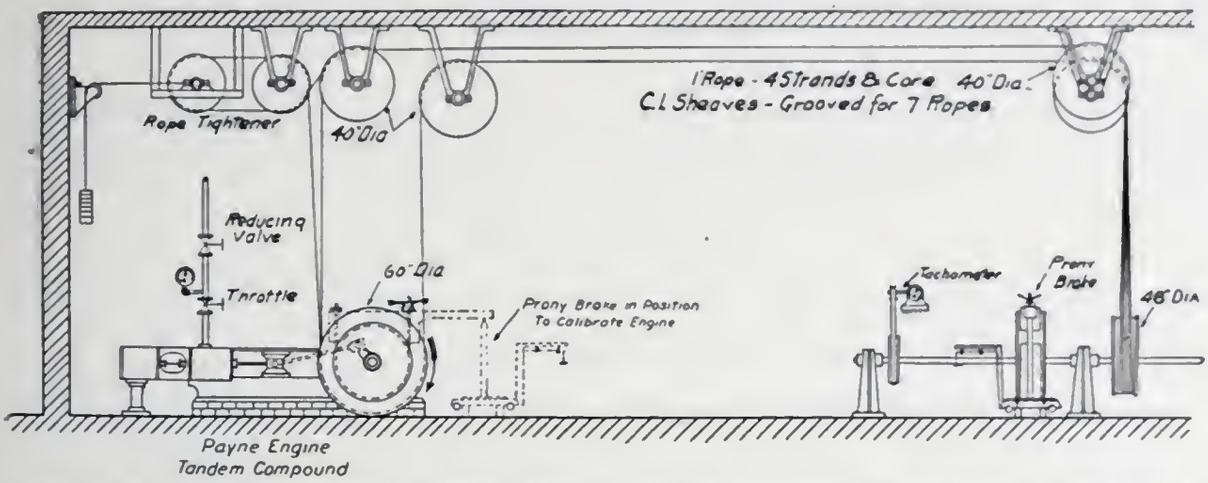

Fig. 4. Diagram of Rope Drive in Carnegie Technical Schools.

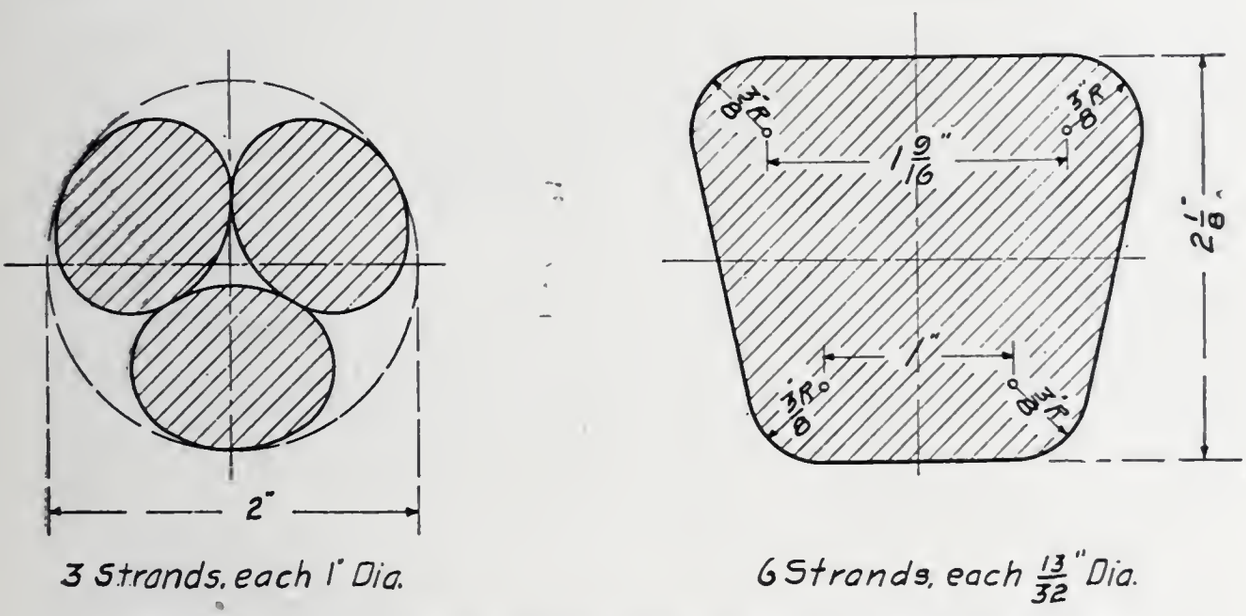

Fig. 5. Section of ropes used in German Rope Tests.

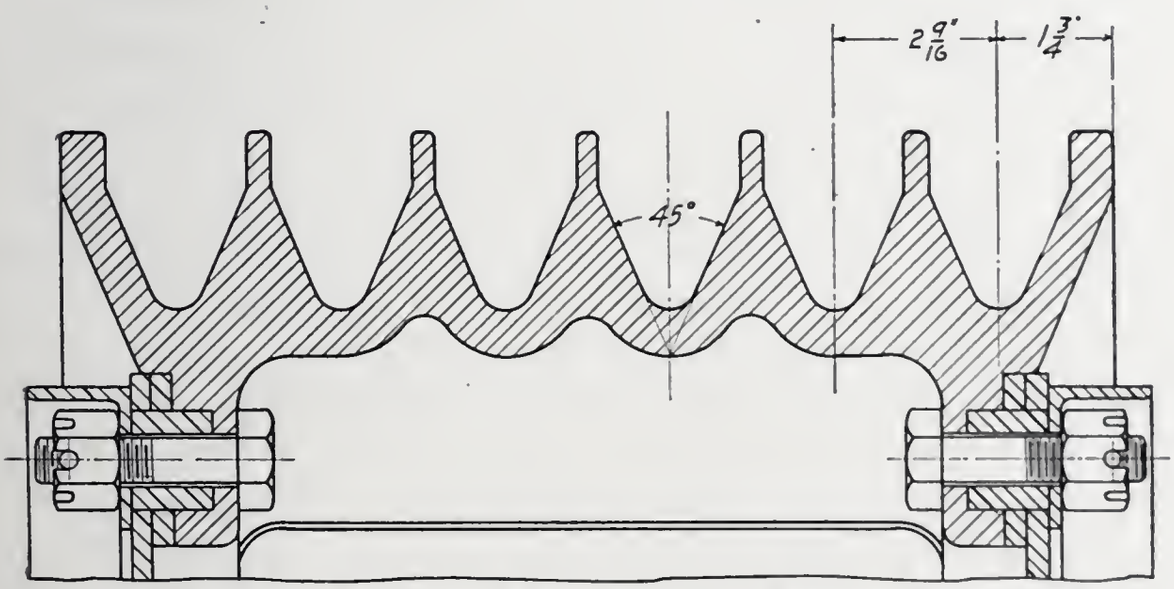

Fig. 6. Profile of Rope Sheave used in German Rope Tests.

sults and second in how they were obtained, I proceed to immediately give the most important results.

GERMAN TESTS

The styles of ropes used in the test are shown in Fig. 5 and Fig. 6 shows the grooving of the sheaves.

Figure 7 is the first really important illustration because it shows the limiting values of all the efficiencies obtained during all the 500 tests which were made. This diagram is worth some study. With only one rope on the sheaves efficiencies of over 97 percent can be attained, and the efficiency stays high

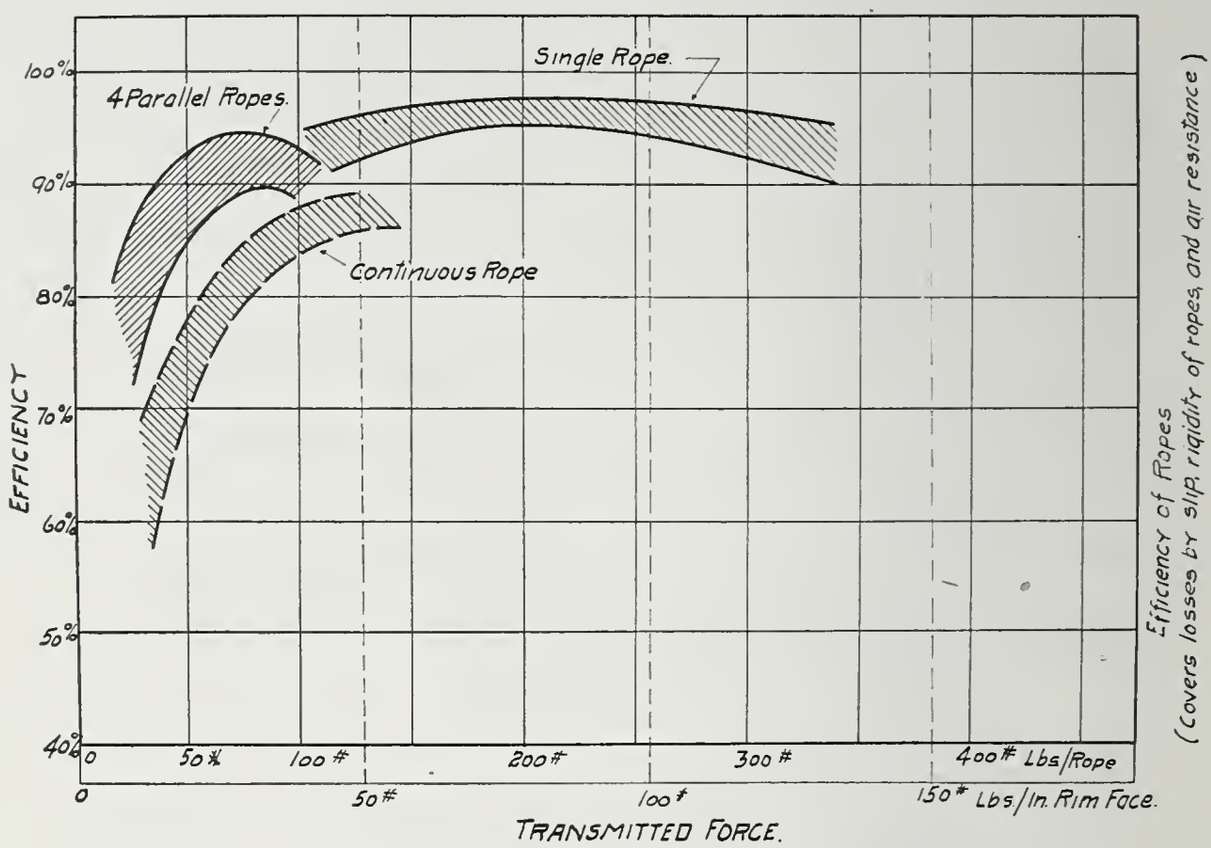

Fig. 7. Limits of Rope Efficiency in German Tests.

over a wide range of transmitted (useful) force. As soon as several ropes are employed the range of high efficiency is very much reduced. The highest efficiency is approximately the same as before but it is reached at a much lower transmitted force. Unfortunately, the electrical equipment limited the transmitted force when four ropes were employed so that the other branch of the curve could not be obtained. It is thus seen that in spite of the great expense of these tests, problems of real value to the rope-transmission engineer have not yet been in-

vestigated satisfactorily. Furthermore, if the highest efficiency was reached with 75 lb. of transmitted force per rope, if four ropes were employed, and if the highest efficiency was reached with about 180 lb. per rope if only one rope was employed, then what law does this decrease of useful force per rope follow if any given number of ropes are employed? Evidently the answer is lacking and the tests only serve to whet our appetite for additional and more valuable information.

The other rather startling information revealed by Fig. 7 is the fact that the continuous rope drive, American System, is inferior to the parallel drive, English System, with regard to maximum attainable efficiency. This fact is likely to arouse comment from the part of those who make a living out of building continuous rope drives. And indeed they have a right to comment and criticize. First, because the tests were not carried to a sufficiently high load per rope, and second, which is much more important, because the tests were made with rope sheaves of a grooving which was not adapted to the continuous drive. In this respect comparison with the tests made on the continuous rope drive at the Carnegie Technical Schools, given later, is interesting.

Figure 7 in itself is sufficient to convince even the ardent admirer of electrical transmission that a properly arranged rope drive between parallel shafts equals electrical transmission with regard to efficiency, or even surpasses it.

It should be understood that bearing friction and losses due to air resistance of rope sheaves are not included in the efficiencies given in Fig. 7, so that the total efficiency of transmission will be lower; bearing friction and sheave resistance vary so much with the detail design that they should, whenever possible, be kept separate from the rope efficiency proper. While Fig. 7 shows the limits of all efficiencies found during the various tests it does not give the influence of the different variables on efficiency of transmission; this influence must therefore be investigated.

The old question was "What should be the velocity of a rope to transmit a maximum amount of power?" This question was answered by theory, paying due respect to centrifugal tens-

ion, with the answer of 5000 ft. per min. The new questions are: "Does practice confirm theory in this case, and at which rope speed is the efficiency of transmission a maximum?" With regard to these two steps, the German tests hold a few surprises in store.

A typical case is illustrated in Fig. 8. The transmitted force was kept constant and equal to 132 lb. per rope. The initial force was 330 lb. per rope. The dotted lines show forces in the rope according to the old theory. The solid lines show observed forces. It will be immediately noticed that according to theory, the slack rope would lose its tension (with the given initial tension) at a speed of 85 ft. per sec., whereas this condition did not arise until a speed of 120 ft per sec. was reached. The original report is full of similar diagrams taken under varying conditions. Evidently the observers were astonished to find this difference between facts and time honored theory, and in consequence took particular pains to be sure about this point. The original report tries to explain the discrepancy by the well known fact that any loading of a rope takes a long time to produce its corresponding stretch and that therefore a high speed rope acts similar to an inelastic band laid over two pulleys. An inelastic band does not stretch under the influence of centrifugal force; its pressure against the pulley remains constant, no matter what the speed is. "Incomplete elasticity" then is quite a help to the rope transmission engineer.

The second part of the question: How does the efficiency of transmission vary with the speed is not so concisely answered, but it appears that it drops very slowly with increasing speed; the drop with increasing speed is, however, so small that it cannot be a barrier to the use of high speeds.

In the German tests the influence of other variables was investigated, namely, that of diameter of pulleys, of initial load on rope, and of an idler pulley.

It was found that the influence of initial load on efficiency is very small, as long as that initial load is sufficient to prevent slip. It was also found that the initial load which is necessary to prevent slip, is in reality much smaller than theory would indicate, so that under average conditions the transmit-

ted force may rise up to 80 percent of the force in the tight rope. The authors of the German report recommend an initial tension of 800 lb. for a two inch rope under average conditions.

The knowledge of this last paragraph is largely academic (with the exception of the last sentence) because sudden changes of load and change of moisture require a high initial tension.

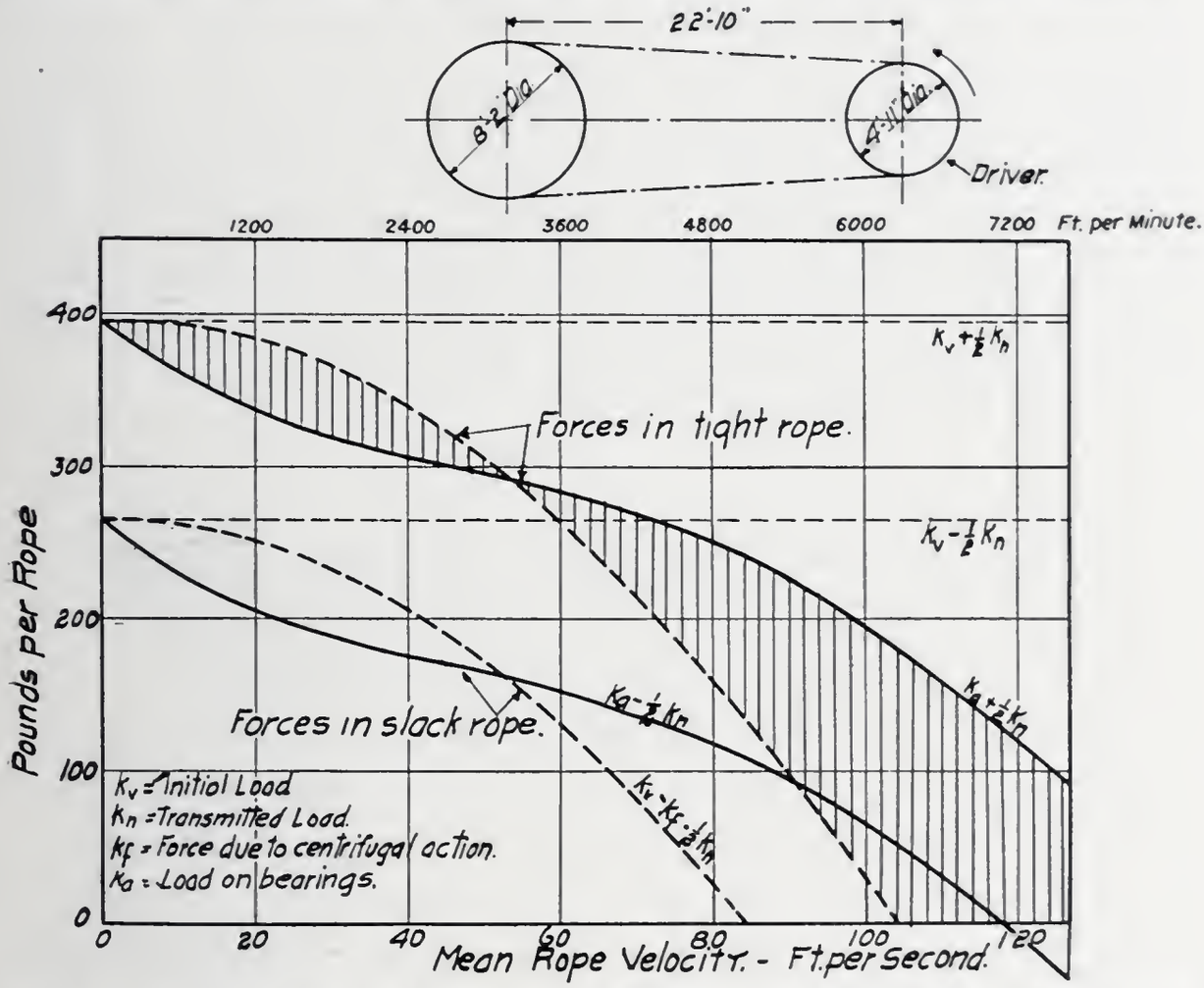

Fig. 8. Theoretical and Actual Influence of Centrifugal Force on Rope Drives.*

The diameter of pulleys was found to have the generally accepted influence. The smaller the pulley, the lower the efficiency. Rope drive engineers will add: "The smaller the pulley, the greater the wear."

The last item investigated by the German commission is the influence of an idler. With rope pulleys of 100 in. and 60 in. diameters and an idler of 40 in. diameter it was found that the efficiency of the drive dropped over 10 percent by the use of

*In the conversion from the metric to the British system the figures have been rounded off. If closer figures are wanted the original report should be consulted. See appendix.

the idler without offering any advantages as compensation for the loss. The deleterious influence of the idler was attributed to the back and forward bending over a comparatively small pulley.

TESTS IN CARNEGIE TECHNICAL SCHOOLS

Turning to the Carnegie Technical Schools tests, we note that the tests were made on a continuous rope drive. As the tests were made, the term "efficiency" includes the following losses: Resistance of all of the seven rope strands to bending over four pulleys and of one rope due to bending over the pulleys of the tension carriage, bearing friction of the four ceiling pulleys and of the pulleys in the tension carriage, air resistance of the ropes and of the rope pulleys with the exception of the rope pulley on the engine shaft and creep of ropes.

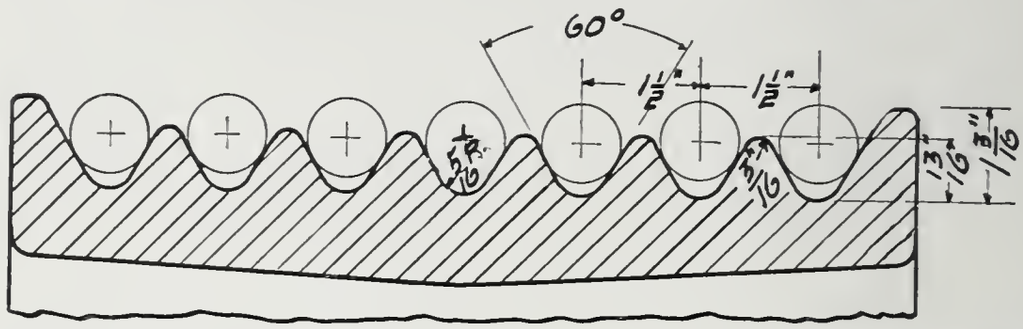

Fig. 9. Profile of Rope Sheave in Carnegie Technical Schools.

Fig. 9 shows the grooving of the sheaves and Fig. 10 shows the results of these tests. The values of the efficiency lie above 80 percent for average load and vary with the speed and with the transmitted power. The variation of efficiency due to change of initial tension was not studied.

In comparing these tests with the German tests of continuous ropes, we are at once struck by the coincidence of results, their averages being also between 80 and 87 percent, but when we dig below the surface, we find that the Carnegie Technical Schools tests give higher efficiencies, because they include the bending of the ropes over the two additional pulleys and the bearing friction of these two additional pulleys. Reduced to the basis of the German tests, the Carnegie Technical Schools tests would probably show efficiencies over 92 percent. The continuous rope then shows practically the same efficiency

as the parallel independent ropes, provided that the grooving is made right. In concluding this paper I wish to state that I have purposely confined myself solely to the efficiency of rope drives, because too little was known about this quantity. I have avoided a comparison between cost of direct electric drive and rope drive, because comparative figures can easily be determined for each individual case.

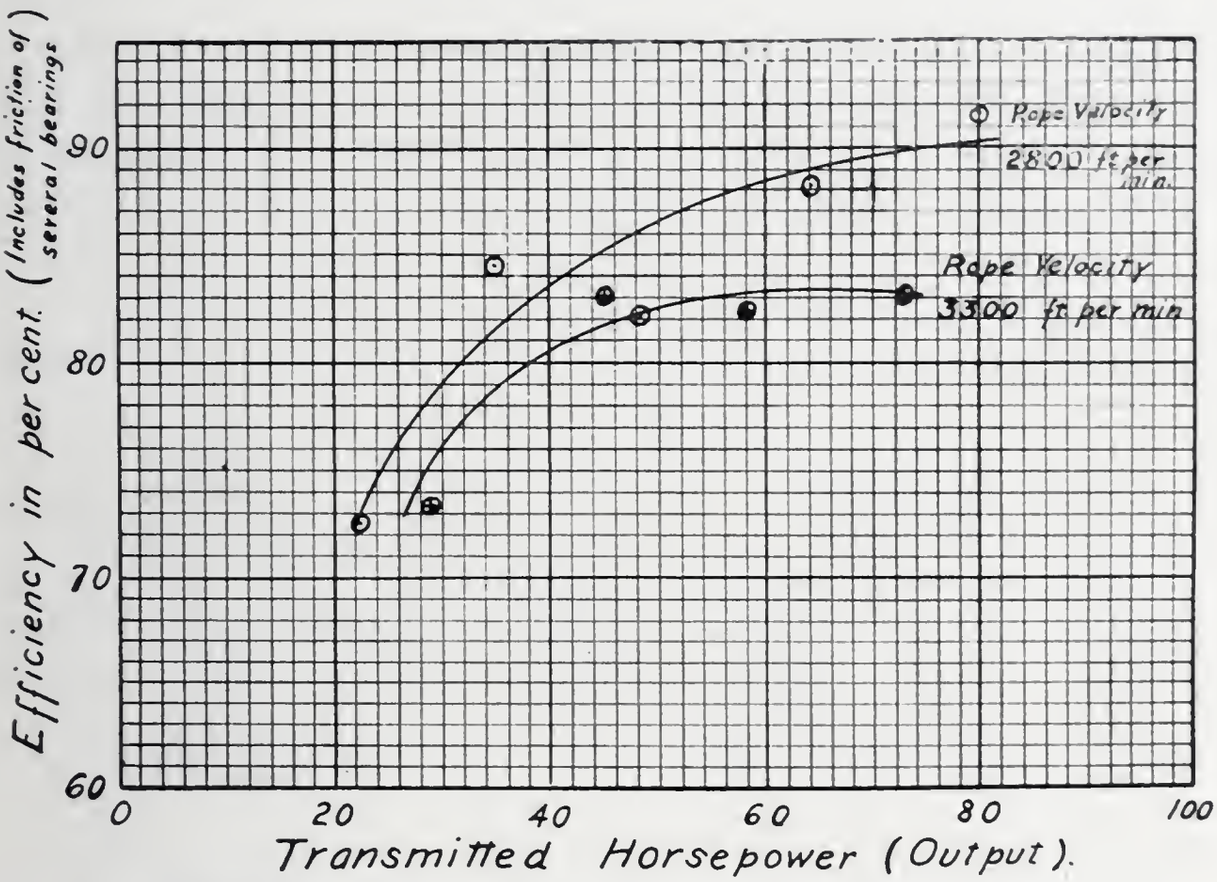

Fig. 10. Efficiency of Rope Drive in Carnegie Technical Schools.

I may also be criticised for not discussing those relations between initial tension, transmitted load, size of rope sheaves and speed which will make the total cost from interest, depreciation (wear) and transmission loss a minimum. I am afraid that I will have to bear that criticism, because I do not know enough to discuss these relations profitably. A great number of expensive tests would be necessary to solve this complicated "function." With the aid of the industries who are interested in rope transmission these tests might be made, but without their aid it cannot be done by myself or my associates, because the Carnegie Technical Schools are operated

above all for the instruction of students and legitimately can do only a limited amount of research work under the heading of "instruction of students."

APPENDIX

MEASURING METHODS USED IN CARNEGIE TECHNICAL SCHOOLS TESTS

The driving engine was calibrated for "power developed at a given speed and a given throttle pressure" the assumption being that with a given steam distribution, a given constant steam pressure and superheat, a given constant speed and the same method of lubrication the power developed by the engine would be the same independent of the time of the test. During this calibration the ropes were removed from the rope sheave on the engine shaft, and the brake beam and strap were applied to the brake pulley on the engine shaft. They were then transferred to the brake pulley on the line shaft, the rope drive was connected up, and the loading on the brake so adjusted that exactly the same speed as before was obtained at the engine shaft for a given throttle pressure (which was kept constant by a sensitive reducing valve). By measuring speed and torque at the line shaft and comparing their product with speed and previously measured torque at the engine shaft, input and output could be obtained. The ratio of the two does not yet give the efficiency of the rope drive, because the receiving, or driven, pulley is located on a long line shaft, whose friction should not be charged against the rope drive.

To determine the friction work the line shaft was driven, with the rope pulley loose, by an electric motor, through a belt pulley and clutch; the input into the motor (amperes at constant voltage) was measured; after removal of the belt a Prony brake was applied to the motor until the same input was reached. Brake torque times speed gives power absorbed by line shaft and belt. Taking the efficiency of the belt to be 90 percent we can figure the friction work of the line shaft. This latter is a small percentage of the total work (about three percent) so that any error in the estimate of the belt efficiency can affect the final result only in so small a degree that it is beyond the limits of observation of the figures on the rope drive.

The method is reliable. Errors are likely to slip in three places: Friction of gage indicating throttle pressure, lost motion in engine valve gear, and slip of tachometer. The fairly good coincidence of results on several tests gives confidence in the observations.

The only valid objection which may be raised, is that the friction of the engine shaft bearings and of the line shaft is less with the rope drive in operation than it is when the friction of the engine shaft and the line shaft are investigated separately. When the engine shaft drives the brake directly, the lifting up by the ropes is absent; when the line shaft runs separately the rope pulley does not turn, but the shaft revolves in it. Both mean increased friction, whose amount cannot be exactly determined; but which makes the rope drive efficiency appear higher than it actually is. Fortunately, the error is small as even a superficial calculation will show.

MEASURING METHODS USED IN GERMAN TESTS

Complete details of the German tests are given in "Mitteilungen ueber Forschungsarbeiten," Heft 56 and 57, published by Julius Springer in Berlin. A list of the important conclusions drawn by Professor Kammerer from these tests is also printed in "Hutte," Des Ingenieurs Taschenbuch, 20th edition, Volume 1, pages 737 to 740.

Testing Equipment. Two massive iron frames, each weighing about 12 000 lb., were mounted upon a rigid steel girder base, weighing about 18 000 lb. One frame "*a*" was held practically stationary by a hydraulic support which measured the rope pull; to eliminate the influence of friction on the indications of this support, the frame rested on 16 hardened steel balls which lay between hardened steel guides. The other frame "a_2" was used for adjusting the rope tension. It rested on planed surfaces and could be moved to any position by a chain and sprockets.

To reduce friction as much as possible, the shafts W_1 and W_2 (which carried the rope sheaves) were mounted in ball bearings. Each shaft carried two overhung armatures of dynamo-electric machines, two of which worked as generators and two of which worked as motors.

By this arrangement a minimum number of bearings was attained, the loading was made symmetrical, and all couplings, clutches, or mechanical dynamo-meters were dispensed with. The driving motors and receiving generators had to be calibrated carefully. This was done by running each set (with ropes off) as a motor generator set, first using one motor as a generator and then the other. The efficiency thus measured included electrical losses, bearing friction and windage. Therefore the rope efficiencies are truly rope efficiencies only, all other losses having been taken care of by the calibration with one exception, namely, that the rope pull somewhat increased the bearing friction; this latter exception was not considered serious, because centrifugal force relieves the bearings partly from the rope pull.

The hydraulic supports (dynamometer for measuring rope pull) were calibrated by the elongation of a standard bar whose elongation had previously been found by direct loading with weights. The bar was fastened (instead of the rope) between the two frames. The elongation was determined by mirror instruments. This expensive method was later replaced by using a thin steel band instead of the test bar; the steel band was loaded by weights in the center. From the deflection and the loading the horizontal pull was computed.

The making of the hydraulic support was difficult; anybody who tries for the first time to make this otherwise most excellent instrument for a great deflection will encounter similar difficulties.

The slip of the ropes was measured by two revolution counters which were started and stopped simultaneously by electro-magnets.

The rope tests lasted from July to October 1905.

For additional data the original report of Professor Kammerer should be consulted.*

*Copies may be obtained from Julius Springer, Berlin, Germany.

TYPICAL ROPE DRIVES FOR MODERN ROLLING MILLS

By A. A. Neave*

In the last ten years rolling mill practice has witnessed a more general introduction of continuous and semi-continuous processes of rolling. These processes require one-pass mills which are stretched in a line in contradistinction to the old type which consists of one stand of housings with a great number of passes. The question of driving these continuous mills has been solved in three ways:

First. By individual motors on each mill.

Second. By a long shaft running along all the mills and driving the separate mills by bevel gears.

Third. By rope drive, driving from one prime mover to the various stands by ropes of varying lengths.

Combinations of these three methods have also been used. Of the three methods, the individual motor is the most expensive in first cost and by no means the most economical in operation because a large number of the motors run idle most of the time; gear drives when run at high speed are noisy and give rise to vibratory stresses, thus leaving the rope drive as a mode of power transmission which is both inexpensive in first cost and smooth and reliable in its operation.

While a great number of various arrangements of rope drives are possible, the writer believes that the two presented in this paper will suffice to illustrate two prominent types:

First. A drive through ropes alone.

Second. A combined rope and gear drive.

Turning first to the power transmission by ropes alone, we find an example in the rope drive at the Aliquippa plant of the Jones & Laughlin Steel Co. in their department for cold rolling tin plate.

In order to enable every engineer in this audience to fully judge this rope drive in its entirity, all of the essential figures have been given.

*Engineer Rolling Mill Department, Mesta Machine Company, Pittsburgh. Read by Prof. W. Trinks.

This drive was installed to transmit power from a compound condensing steam engine to three five-stand trains of 24 in. cold rolls.

The engine is a heavy duty Corliss of the cross compound type running at a speed of 70 r. p. m. The high and low pressure cylinders are respectively 30 in. and 60 in. diameter by 60 in. stroke.

The driving rope sheave on the engine shaft is 15 ft. diameter by 14 ft. 8 in. face and is grooved for 60 two inch ropes from which the power is transmitted to three driven shafts, each carrying wheels grooved for 20 two-inch ropes, the wheels being respectively 26 ft. 3 in. diameter, 25 ft. 8 in. diameter and 25 ft. diameter and weighing approximately 45 tons each.

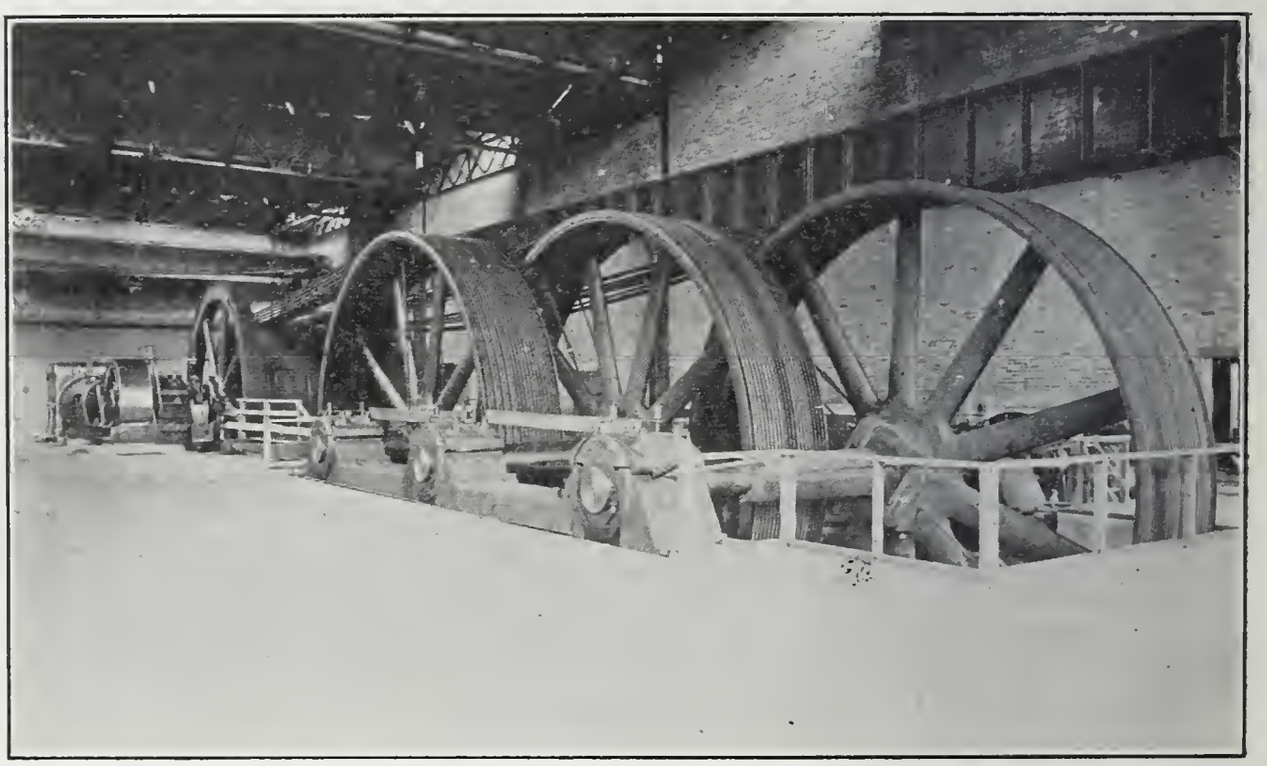

Fig. 11. General View of Rope Drive at the Aliquippa Works of the Jones & Laughlin Steel Company.

The engine and rope drive are located in a separate building and the driven shafts of the rope drive are connected to the roll trains in the usual manner by spindles and couplings.

The three roll trains which run at respectively 40, 41 and 42 r. p. m. are arranged in tandem style and the plate is fed through the first train of rolls from which it is conveyed to the second train of rolls and then to the third train of rolls.

This arrangement permits a continuous feed of plate through the rolls and in order that there may be no crowding between passes the trains run at the speeds mentioned, which increase the speed of rolling at each successive pass.

It will be noticed that a semi-continuous process of rolling is obtained by this arrangement and that the load on the engine is fairly uniform.

The whole layout combines economy of operation with comparatively small cost of installation. Economy of operation includes the advantages accruing from continuous processes, namely greater output per man, or what amounts to the same in the end a smaller number of men for a given output.

The engine and rope drive are shown in Figs. 11 and 12.

It is questionable whether the same advantages could be had without the use of ropes as the speed is too slow for direct connection to motors and because a gear drive is apt to mark the plates, which would require more tin to obtain a smooth finished product.

In a mill where a semi-finished product is rolled gear drives are therefore not advantageous. In a mill where the product is not yet near the finished stage, gear drives are not so objectionable, and thus we find in the 16 in. continuous skelp mill in the National Works of the National Tube Company a combined rope and gear drive.

This drive was installed to transmit power from a compound condensing steam engine to nine stands of 16 in. rolls.

The engine is a heavy duty Corliss of the tandem compound type running at a speed of 84 r. p. m. The high and low pressure cylinders are respectively 38 in. and 70 in. diameter by 60 in. stroke. The driving rope sheave on the engine shaft, which also acts as a fly wheel, is 20 ft. diameter and is grooved for 36 two inch ropes from which the power is transmitted to a second shaft carrying a 24 ft. diameter rope wheel grooved for 60 two inch ropes. From the second shaft power is transmitted to a third shaft carrying a 24 ft. diameter rope wheel grooved for 24 two inch ropes.

The engine shaft and the driven rope wheel shafts are connected to three gear drives in the usual manner by means of

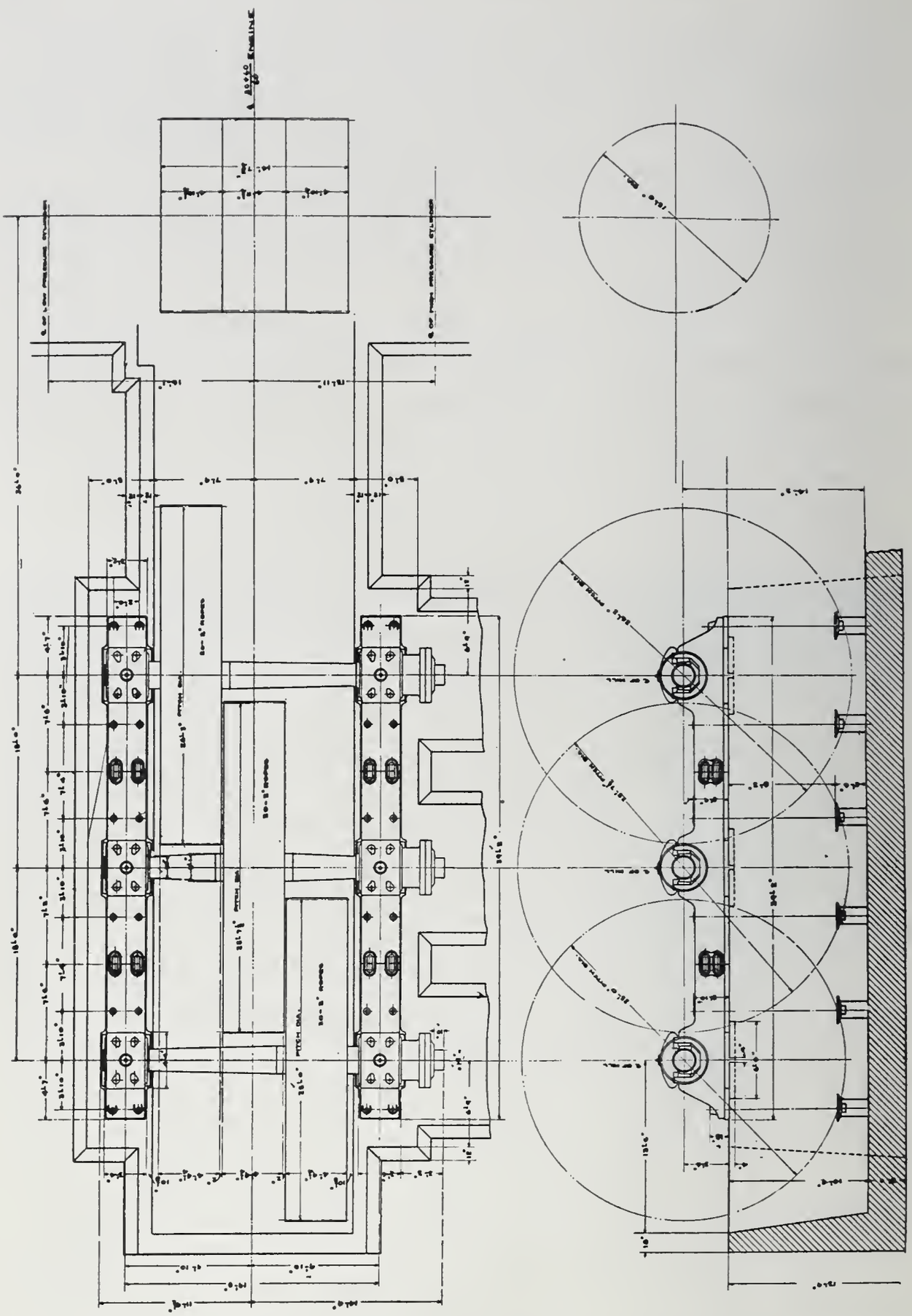

Fig. 12. Plan of Rope Drive at the Aliquippa Works of the Jones & Laughlin Steel Company.

spindles and couplings. Each of the gear drives is coupled to three stands of two-high rolls. The required direction of rolling is obtained without employing idler gears by coupling alternately to the bottom and top pinions.

The nine stands of rolls are arranged in tandem style, in groups of three stands each, each stand making one pass.

The slab is conveyed from the shears by a roller table to the first pass.

Fig. 13. General View of Rope Drive at the National Works of the National Tube Company.

As originally designed passes 1, 4 and 7 were straight passes and passes 2, 3, 5, 6, 8, and 9 were provided with vertical edging rolls in addition to the horizontal rolls. This layout has since been changed, the only edging rolls being now at the 7th pass. Passes 1 to 6 inclusive are now grooved passes while 7 to 10, inclusive, are flat passes. The edging rolls after the 10th pass have also been removed, the space being now occupied by an automatic flying shear which cuts the skelp to any desired length without interfering with its forward speed.

This arrangement, in addition to maintaining a fairly uniform load on the engine, allows the three consecutive passes

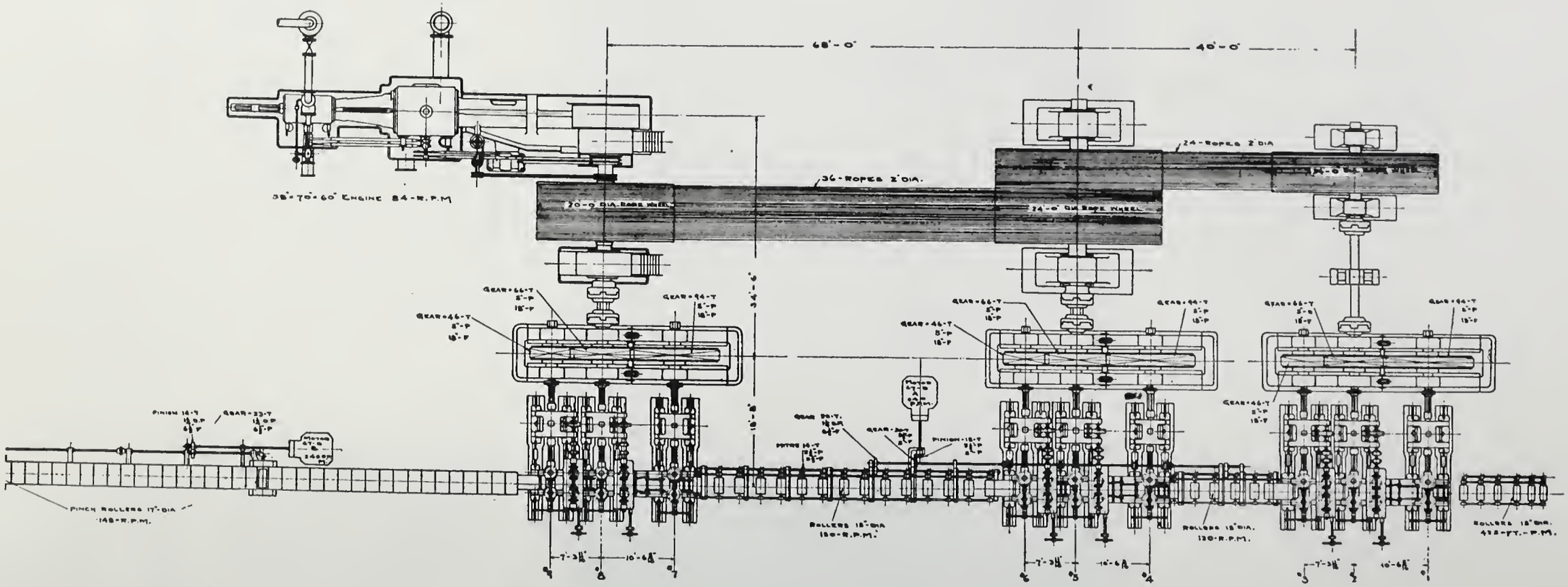

Fig. 14. Plan of Rope Drive and 16 inch Continuous Mill at the National Works of the National Tube Company.

forming each of the groups to be arranged very close together; the speed of rolling is changed between each of the groups, thus permitting a fairly high speed of the piece entering the first pass without abnormally high speed of delivering from the ninth pass.

Figures 13 and 14 show the general arrangement of the engine, rope, drive and mills.

It will be noted that both of these drives employ parallel ropes, the English system. The general tendency in rope drives for rolling mills seems to favor parallel or individual ropes in preference to the continuous rope drive or American system. In drives with individual ropes, it is common practice to use more ropes than necessary for the transmission of power so that the breaking or jumping off even of several ropes will not shut down the mill. The ropes may also require to be removed on account of excessive stretching. It is customary to resplice the ropes on Sunday, if necessary, so that there will be absolutely no possibility of a shut-down during the week.

In the continuous system a break in the rope would necessarily mean a shut-down and it appears that the dread of the possibility of a shut-down has kept rolling mill engineers from adopting the continuous rope system. It is not intended to pass judgment here on the relative merits of the two systems and the writer fully acknowledges the advantages of the continuous rope in places where shut-downs of short duration are not as costly as they are in a rolling mill.

DISCUSSION

Mr. W. P. Flint: I would like to have Prof. Trinks' refer again to Fig. 7 and ask if any tests were made on the multiple rope drives at tensions per rope corresponding to those in the single rope drives.

The band representing the multiple rope tests shows a slight downward trend at the highest observed tensions. It is a question whether, if the rope tension had been doubled, this tendency would have been confirmed.

The Author: Unfortunately, Mr. Flint, the capacity of the equipment was limited in those tests. They had four

100 h.p. motors and generators, and were afraid that the machines would be burned out if more than 200 h.p. were transmitted. This is the greatest drawback of these tests, namely the limitation of the equipment.

Mr. W. P. Flint: It looks to me that you would not have done very much violence to your data if you had used a continuous band to represent both the single and multiple rope tests.

The Author: I tried to refrain from doing violence to somebody else's work, but give the data as I found them.

Mr. Walther Riddle: I would like to know a little more about the rope used in these tests.

The Author: That should have been stated. The ropes used in the German test were good American hemp ropes from the Philippine Islands and the rope which we used at the Carnegie Technical Schools was supposed to be of the same nature. If a representative of the Dodge Mfg. Co. is here, he could easily confirm or deny it. Was that good Philippine Island hemp, Mr. Rose?

Mr. T. L. Rose: The rope in question was considered a high grade hemp rope.

The Author: I believe there is a continuous rope drive at the plant of the Sheet and Tube Company, in Youngstown. I know that there is a rope drive and I am almost sure that it is continuous. I have seen it in operation and it seems to work well.

Mr. T. L. Rose: There is an "American System" rope drive at the Youngstown Sheet & Tube Co.'s plant, at Youngstown, Ohio, but this was put in before my time in this field and I only know that it was an "English" or Multiple Drive, and was changed to the "American System" in order to increase the efficiency without adding more Ropes. I understand the drive is still in operation and giving good results.

There is also an 800 h. p. American System drive at the Republic Iron & Steel Co.'s Bonnell Works. Youngstown, Ohio,

on very short centers, which is reported satisfactory. This drive has been in operation about four years.

THE AUTHOR: The fact that you have several successful mill drives in operation made me wonder whether Mr. Neave's explanations met with your approval, and since you are a leading exponent of the continuous rope it appeared to me that you might give us some of your experience on this question.

MR. T. L. ROSE: The principal reason or preference for multiple rope drives, for rolling mill work, as stated in Prof. Trink's discussion, is the fear of the rope breaking or coming off during the run. On important work like rolling mills, plate glass plants, and rubber plants, engineers familiar with this class of work figure a big margin for safety factor, and I do not know a better rule than Mr. Julian Kennedy's, just quoted by Prof. Trinks, "Figure enough and multiply by two."

The "English," or Multiple Rope Drive has its good features, but as Prof. Trinks has introduced me as the opponent to this system, I will say a few words for the "American System." It adapts itself to the conditions we find. It matters not whether the centers are short or long or whether the shafts are parallel or at right angles. One may be horizontal, the other vertical, but they can be connected up, with this system of rope transmission. There is only one rope to splice. The tension is always the same, giving the maximum efficiency of the rope, which allows smaller and fewer ropes to be used and permits the "American System" in many places where wider sheaves could not be used on account of space on shafts,—less friction load and less cost of maintenance.

As shown in Prof. Trink's discussion of tests, which are facts, each rope drive must be treated according to the conditions you have to meet. A rope drive is not a stock article but is an engineering proposition.

A FEW REMARKS ON THE MANUFACTURE AND PROPERTIES OF IRON AND STEEL

By H. P. Tiemann*

Owing to the limited time allotted, as well as to the vastness of the subject, it is proposed in this paper to give only a brief description of the various processes employed in the iron and steel industry and the resulting products together with the fundamental principles involved.

ORE

The term ore signifies a natural mineral substance containing a sufficient proportion of some metal, either free or combined with one or more other elements, to render its extraction profitable. Intermixed with the mineral substance is a certain amount of earthy matter, principally sand or clay, technically known as the "gangue."

Iron almost never occurs in nature in the free or metallic state but in chemical combination with certain elements, principally oxygen, from which it must be separated or reduced before it becomes of practical value.

REDUCTION

In the production of metallic iron two things are necessary:

First. To reduce the iron, i. e., separate it from the oxygen with which it is chemically combined.

Second. Remove the gangue with which it is mechanically mixed.

Reduction is effected by the aid of some substance which, at a high temperature, has a greater attraction or affinity for the oxygen than the iron has. Some form of carbon, coke or charcoal, has been found more suitable and economical than any other for this purpose.

Presented before the Structural Section, March 7th, and published in the April, 1911, Proceedings.

*Metallurgist with the Carnegie Steel Company, Pittsburgh.

The gangue is removed by melting it, and, to assist in this it is usually necessary to add some other material, called a "flux," to combine with it and render it sufficiently fusible; the resulting compound is termed the "slag" or "cinder." In the earlier processes part of the iron oxide in the ore itself was used for the flux, but at present the iron is too valuable to be wasted in this way, and so lime, which also better answers the purpose, is added specially.

ORIGINAL METHODS OF SMELTING

Probably the oldest method of operating was to dig a hole at the top of a hillside, forming a crude fireplace or hearth, which was filled with ore and charcoal. The top was then covered over, a hole provided in the top for a chimney, and another at the bottom so the air could enter and burn the fuel. The prevailing winds were depended upon for the draft.

The improvements made from time to time have consisted in supplying air under a slight pressure instead of depending upon the natural draft, building the furnace of bricks instead of earth and stones, etc. At first the temperature was comparatively low and the reducing conditions correspondingly weak so the iron was never actually melted and was soft, that is, contained very little cabron. There was always a certain amount of slag intermixed with it, the same as with puddled iron.

To obtain greater output, and at the same time reduce the proportion of fuel, the height of the furnace was gradually increased, and with it the temperature and the reducing action, the blast pressure also being increased, so that eventually the product was fused, and in consequence contained a considerable percentage of carbon, constituting cast iron or pig iron.

BLAST FURNACE

The modern blast furnace is a vertical circular shaft built of fire bricks which are usually sheathed with steel plates. The interior of the shaft is not perfectly perpendicular, but contracts gradually both ways from the widest point, which is slightly below the middle, called the "bosh." The inside diameter at this point is one of the measurements given to indicate the size of a furnace. Thus, a furnace 90 by 21 means one that

is 90 ft. high and 21 ft. in diameter at the bosh. At the bottom, however, where the molten iron collects, the walls are perpendicular; this point of the furnace is called the "hearth" or "well."

The raw materials for the charge consist of: Ore, which, as we have already seen, is composed of oxide of iron mixed with impurities or "gangue"; Coke, to reduce the iron and also to supply the heat required; Limestone, to "flux" the gangue, i. e., to make it sufficiently fusible, and also for its chemical effect on the process.

The air for burning the coke, called the "blast," is introduced into the furnace at a point just above the hearth through a series of pipes known as "tuyeres," and has a pressure of about 10 to 15 lb. per sq. in. It is preheated in huge "stoves," as this effects a great economy in fuel.

The raw materials are charged continuously at the top, and the furnace is always kept filled to a certain point. Everything used is very carefully analyzed and weighed or measured, as it will not do to leave anything to rule of thumb.

As the charge descends, it is gradually heated and the iron reduced, until finally the whole melts and collects at the bottom in the hearth. The iron is tapped out at intervals through the "iron notch" at the bottom of the hearth. The slag, which is only about one-third as heavy as the iron, floats on top of it, and is tapped out at more frequent intervals through the "cinder notch," which is above and to one side of the iron notch.

At one time all the iron was run into sand beds in which were shallow depressions or molds, and the name "pig iron" comes from the fancied resemblance which iron cast in this way bears to a litter of suckling pigs, and the runner to which the pigs are attached is called the "sow." The best modern practice is to cast in iron or "chill" molds to avoid the sand which always adheres to the outside of the pig when cast by the former method. In large plants the metal is tapped into ladles and used immediately in some process for the manufacture of steel before it has time to solidify. The modern furnaces have a daily capacity of about 300 to 600 tons.

Practically all the phosphorus and manganese in the raw

materials will appear in the pig iron, but the silicon and the sulphur are, to a certain extent, under control by regulating the percentage of lime in the slag. The iron also contains about three to four percent of carbon.

Pig iron or cast iron, as such, can only be made into finished objects by casting it in molds, as it contains so much carbon that it cannot be forged or rolled. To convert it into wrought iron or steel it is necessary to "refine" it, that is, remove the impurities as far as possible, or to a certain extent.

The old method of producing wrought iron from the ore in one operation is now called the "direct process," in contradistinction to the present or "indirect method," which consists in first making pig iron and then refining it, as it is not possible to regulate the process so only a limited amount of carbon, etc., will appear in the iron. The reason the direct method has passed out of use is because the resultant product is in a pasty state and its handling is very costly because of the labor and the relatively small units, while pig iron and steel, which are made in a fluid condition, can be handled largely by gravity, and hence cheaply and in large quantities.

ACID AND BASE

We must now digress for a moment to consider a subject which at first sight appears complicated, but is in reality very simple, and that is the meaning of the terms "acid" and "base."

In chemistry it is considered that every substance is composed of one or more simple substances or "elements" and, depending on their properties, these elements are divided into metals and non-metals. In metallurgy bases are usually the oxides of the metals, and acids the oxides of the non-metals. This is the most practical definition, as the one ordinarily given, that an acid, for example, is a substance which has a sour taste and turns blue litmus paper red, is not broad enough to cover the present case. In metallurgy the principal acid is silica (pure sand), which has no effect on litmus paper and no taste whatever. Iron oxide is a base, and another, and the most important, is oxide of calcium or lime.

Bases and acids have the property of combining together to form compounds which are not easily split up, while bases do not combine with bases, nor acids with acids, to form such stable compounds.

WROUGHT IRON

Before any of the usual methods for making steel were known, the soft iron prduced by the direct process was termed "wrought iron" (or, if higher in carbon, "wrought steel") from the fact that it was hammered or worked. The term now means any soft iron containing a considerable proportion of intermingled slag. The principal method for its production is known as "puddling."

PUDDLING PROCESS

This process was invented by Henry Cort in 1784, and has been slightly modified since then, but not to any extent within the last sixty or seventy years. In present practice pig iron is melted down on the hearth of a reverberatory furnace lined with oxide of iron, which serves to protect the iron walls and also forms the greater part of the slag. This oxide, and the oxygen in the gases passing over the hearth, oxidize the impurities in the iron and, since the slag is basic, a large part of the phosphorus (which is oxidized to phosphoric acid), usually some of the sulphur, and practically all of the carbon, silicon and manganese are removed from the iron. As these impurities are eliminated, the metal grows more and more infusible, and hence pasty, until finally it becomes completely solidified. It is worked constantly at this point to insure the proper oxidation of the carbon, and is then collected into large "balls" weighing about 100 to 200 lb. each, and taken to a machine where it is "squeezed" to remove the greater part of the slag with which the particles of iron are mixed. After this it is rolled into long, narrow "flats," in which condition it is known as "muck bars." These are cut up into short lengths, a number of which are piled together and reheated, and the "pile," as it is called, is then rerolled into finished or "merchant" material. With each additional heating and working a further amount of slag is

removed, and up to a certain point the quality is improved, but the elimination is never complete, and the slag remaining occurs in long threads or rods which serve simply to break up the continuity of the iron and form lines of weakness. This slag also gives the fracture of wrought iron its characteristic barked or fibrous appearance.

A puddling furnace usually takes a charge of from 400 to 600 lb., and the process requires about one and one-half to two hours.

WROUGHT IRON FROM SCRAP

Instead of obtaining all the iron needed in a given plant by puddling, as just described, it is usually customary to buy up a certain amount of iron scrap which, in addition to that produced in the plant itself, is heated and re-rolled into finished material. Before the manufacture of steel by the bessemer or the open hearth process, the iron rerolled from scrap was of at least as good quality as that obtained from muck bars. Now that such great quantities of steel are made, however, it frequently happens that some of it, both low and high carbon, gets mixed in with the wrought iron scrap, and the result is a material containing pieces of steel and iron which are not properly welded together.

BESSEMER PROCESS

This process was discovered by Sir Henry Bessemer about 1855 in England and, it is claimed, by William Kelly at an earlier date in this country. It consists in placing molten pig iron in a suitable vessel or "converter," and then blowing cold air through it. The oxygen in the air attacks the impurities, and their oxidation (which is as much combustion as when coal or coke burns) supplies so much heat, and so rapidly, that at the end of the process the metal is several hundred degrees hotter than at the commencement, and the resultant steel is in a perfectly fluid condition.

The converter is egg or pear-shaped (the German word for it is "Birne," meaning pear) provided with a number of holes or "tuyeres" at the bottom, through which the air enters under a pressure of 20 to 25 lb. per sq. in. At first it was lined with

pieces of silica rock which, as we have already seen, is acid, hence no phosphorus could be removed as any which was oxidized to phosphoric acid was reduced immediately and returned to the iron. To effect its elimination it is necessary to have a basic lining to permit of a basic slag (a basic slag would attack and wear away an acid lining), which was first successfully introduced by Percy and Gilchrist about 1879, and consists of crushed burnt dolomite (a mineral composed of the carbonates of lime and magnesia) mixed with a little pitch or tar to bind it together. A certain amount of lime is added to each charge to form the slag. In this case the oxidation of the phosphorus is depended upon for a certain amount of the heat needed. The original process in which no phosphorus is removed is called the "acid bessemer process," and the later modification, in which phosphorus is removed, the "basic bessemer process."

The progress of the operation is indicated by the appearance of the flames issuing from the mouth of the converter. At first only the silicon and the manganese are oxidized, and the flame is very weak. Later, when the carbon burns, it becomes so brilliant that special dark glases must be worn to protect the eyes when observing it. Finally, when nearly all the carbon is gone, the flame becomes less brilliant and much shorter, or "drops," indicating that the action is complete. The metal is then poured into a receptacle called a "ladle," from which it is run into ingot molds through a hole in the bottom. As the steel is fluid, the slag, which is very much lighter, is enabled to rise to the top, and in this way a very perfect separation results, so that practically none appears in the finished steel; *this constitutes the present distinction between steel and wrought iron.*

In order to give the steel the desired composition, carbon, manganese, etc., are added to it in the converter or while it is running into the ladle.

In the basic process there is a further period after the "drop of the flame," called the "after blow," during which phosphorus is oxidized and passes off into the slag.

In this country ordinary bessemer converters have a ca-

pacity of from 10 to 15 tons per heat, and the time for a heat is about ten to fifteen minutes.

For steel to be of good quality the phosphorus which it contains must not be above 0.1 percent, and for some purposes it must be considerably lower. Consequently, in any acid process, it is necessary to have the original materials contain less than the amount specified in the finished steel. This fact causes pig iron to be classified as "bessemer" and "non-bessemer," depending on whether it does not or does contain over 0.1 percent of phosphorus. These names are also applied to the ore according to the respective grade of pig iron which can be made from it. In this country there is no large deposit of ore containing enough phosphorus (for the extra heat needed) to make pig iron suitable for the basic process, hence, only the acid process is employed, and pig which contains more than 0.1 percent of phosphorus must be treated by the basic open hearth or the puddling process.

OPEN HEARTH PROCESS

This process, invented by Sir C. W. Siemens, was first used commercially in 1865. It somewhat resembles the puddling process with the great difference, however, that the metal is always molten except at the beginning during the melting down of any solid materials in the charge.

The furnace, known as an open hearth or Siemens furnace, is of the reverberatory type, and the fuel is either gaseous or liquid (oil)—never solid. Its chief peculiarity lies in the means employed for securing the very high temperature necessary to keep the charge molten, particularly towards the end of the process when nearly all the impurities have been removed. To do this, the air alone, or both the air and the gas, must be preheated. At each end of the furnace, below the floor level, are flues or chambers connecting the furnace with the stack or chimney. These flues, called "regenerators," are filled with "checker work," that is, firebricks laid in such a way that small passages are left. The air, or the air and the gas separately, go through one set of regenerators before entering the furnace where they mingle and burn. The waste gases leave the furnace

at the other end, and then pass through the other set of regenerators before reaching the stack. The direction of the gases is reversed at regular intervals, so that the regenerators which are heated by the waste gases during one period give out a part of their heat to the incoming gases during the following period and, in consequence, the temperature of the combustion is much higher than could be obtained in any other way.

The charge ordinarily consists of pig iron, either solid or molten, and various kinds of scrap. The same remarks about the acid and the basic bessemer process also apply here: In the acid process, where an acid (sand) lining is employed, the charge must not contain more phosphorus than is permissable in the finished steel, while with a basic lining (crushed burnt dolomite), it may vary widely, as it is nearly all removed by the basic (limy) slag which can then be employed.

The present size of furnace has a capacity of 50 to 60 tons or more per heat, and the time for a heat is about eight to twelve hours.

The bath, consisting of the molten metal covered with a thin layer of slag, looks like boiling porridge from the bubbles of gas formed by the oxidation of the carbon. The progress of the purification is determined by the appearance of the fractures of "test ingots," made by casting samples in a small mold, then quenching and breaking them.

When the bath is sufficiently purified and at the proper temperature it is tapped into a ladle in which the addition of carbon, manganese, etc., are made in much the same way as in the bessemer process.

CRUCIBLE PROCESS

The crucible process, invented by Huntsman in 1740, consists in the melting of various grades of steel or iron in crucibles, certain additions where necessary (e. g. ferro-manganese, charcoal, etc.), and very pure materials must be employed, and practically no purification takes place. The usual charge for a crucible in this country is 100 lb., and three melts are made every twelve hours. As the work is done by hand the product is very costly, and hence is used only for special purposes, such as the manufacture of tool steel, watch springs, etc.

ELECTRIC PROCESSES

During the past few years electric processes have come into a certain amount of use, but their application is still limited owing to the higher cost involved. Electricity is used smply as a means for supplying heat, and does not effect the actual purification of the metal, *per se,* as in the case of electrolytic refining of copper.*

PROPERTIES

Wrought iron as made at present rarely exceeds 0.10 percent carbon, corresponding to a very soft grade of steel. The comparative physical properties under tensile test are about as follows:

	Wrought Iron.	Soft Steel
Tensile strength, lb. per sq. in.	45/55000	45/55000
Elastic limit, lb. per sq. in.	25/30000	27/32000
Elongation in 8 in. minimum percent	15	28

When higher tensile strength and elastic limit are required, steel is now universally employed.

In comparing the quality produced by different processes for steel of the same composition, the following is the generally accepted order, subject to modifications under certain conditions and for special purposes: Crucible, electric, open hearth, bessemer.

The physical properties are affected by: chemical composition, heat treatment and method of working, and size or shape. Further, these variables are generally interrelated.

Increase in the percentage of an element present usually increases the strength and elasticity and reduces the ductility. With similar composition and other conditions equal it has been found that proportional increases in carbon produce slightly greater effects in acid than in basic steel.

H. H. Campbell has done a large amount of work to deter-

*The subject of electric furnaces and processes was quite fully covered in a paper recently read before the Society by P. Mc. N. Bennie and published in the January, 1911, issue of the Proceedings.

mine the effect of different elements on the tensile strength. His formulae, as modified by Merriman, are as follows:

Acid Open Hearth Steel:

$40\,000 + 68\,000\ C + 100\,000\ P + 80\,000\ CM =$ Tensile strength, lb. per sq. in.

Basic Open Hearth Steel:

$38\,000 + 65\,000\ C + 100\,000\ P + 9\,000\ M + 40\,000\ CM =$ Tensile strength, lb. per sq. in.

In these formulae C, P and M are the percentages of Carbon, Phosphorous and Manganese and CM is the product of the percentages of Carbon. and Manganese.

HEAT TREATMENT

In its broadest sense this is the application of heat to assist in the mechanical operations of manufacture as well as the application of heating and cooling alone to effect certain beneficial results. In its special sense it is the latter only. In the course of manufacture the heating may be beneficial or harmful, and if harmful a special corrective treatment may be required.

Special heat treatment may be classed under three heads: Hardening, Tempering, Annealing.

Hardening is sometimes produced by cold working, but is ordinarily accomplished by heating to above a certain temperature (known as the critical point), followed by rapid cooling, usually in water or in some other liquid. The degree of hardness obtained will, in general, vary directly with (*a*) the percentage of carbon, (*b*) the rate of cooling, and (*c*) the temperature above the critical point from which cooling takes place.

Tempering signifies the mitigation or removal of the brittleness which always results from hardening. The hardness is also somewhat reduced although this is not the real object of the treatment, and the steel is left relatively hard and tough instead of very hard and brittle. Tempering is effected by reheating to about 200 to 330 deg. cent. (390 to 625 deg. fahr.), depending upon the purpose for which the material is intended.

Annealing has for its object (*a*) completely undoing the effect of hardening, leaving the steel in its softest and most ductile condition; (*b*) removing any strains set up by too rapid

cooling, particularly if the rate is unequal in different parts of the piece; and (*c*) refining the grain. For the first two it is sufficient to heat below the critical point, say to 600 deg. cent. (1110 deg. fahr.), but for the last the temperature must be raised to above the critical point. The cooling is usually slow.

The finishing temperature (i. e., the temperature at which work ceases) has an important effect on the physical properties of a piece. If the temperature of working is carried close to the critical point, the grain will be fine, and the physical properties will be improved. In general, the larger the section the higher the finishing temperature and the slower the cooling. For this reason, with the same composition, the larger the sections the lower the tensile strength and elastic limit. If the work be continued until the critical temperature has been passed the tensile strength and elastic limit are considerably increased while the ductility is lowered. The extreme case of this is where the material is worked perfectly cold.

Cold working may consist in (*a*) slightly reducing the cross-sectional area by rolling, hammering or drawing; (*b*) distorting the material by bending or twisting; and (*c*) punching or shearing. The effect is due to the permanent deformation of the crystals or grains from their normal shape which, on account of the rigidity of the metal when cold, they can regain only by annealing which restores the original properties if the cold working has not been excessive.

Cold rolling, cold hammering and cold drawing are employed (*a*) for the effect upon the physical properties; (*b*) where extreme accuracy as to size is required; and (*c*) to obtain a very smooth even surface. Cold twisting is applied to certain bars for concrete construction. By cold working the tensile strength may be increased about 20 to 40 percent, and the elastic limit 50 to over 100 percent; in the case of wire these figures may be even higher.

Cold bending and cold pressing (cupping, dishing and flanging) are resorted to more to obtain some desired form; also to get greater stiffness, but rather from this form than from any effect on the metal due to the cold working involved. Cold shearing and punching affect the metal to a certain depth

from the sheared or punched surface, making it hard and brittle so that it is very liable to cause cracking if subjected to bending without either annealing, or else machining of the embrittled portion. This effect seems to be proportional to the thickness of the piece and to the percentage of carbon, etc.

EFFECT OF SIZE AND SHAPE.

On account of the relatively high finishing temperature, the tensile properties of similar material above a certain size are somewhat reduced, and for very small pieces, with relatively low finishing temperatures, the tensile strength and elastic limit will be increased while the ductility will be reduced. These effects are usually taken account of in specifications for material respectively above $\frac{3}{4}$ in. and below $\frac{5}{16}$ in. thick.

The elongation and reduction of area up to a certain point are increased by increase of ratio of the width to the thickness.

DISCUSSION

Mr. R. B. Woodworth: The term "steel" has a very wide connotation and in reading literature on this subject it is well to bear in mind that the difference in some grades between steel and wrought iron is very slight. Mr. Tiemann states that the term "wrought iron" now means any soft iron containing a considerable portion of intermingled slag, however manufactured, and that freedom from slag constitutes the present distinction between steel and wrought iron.

Mr. Tiemann has in mind here what is ordinarily known as mild or low carbon steel, which is the main material for bridge building and other structural uses but which is not the kind of material called steel in text books issued 50 years ago. The word steel means today several different things and in its exact use must be modified by some term defining which one of these various substances is intended.

Previous to 1860 there were three important varieties of iron: wrought iron, a soft iron characterized by nearly complete freedom from carbon which was easily malleable but not capable of hardening by quenching; steel, an iron with a medium carbon content sufficient to make it capable of hardening on sudden

cooling but not sufficient to make it brittle when cooled slowly; cast iron, an iron with high carbon content and brittle when cooled either gradually or suddenly from all degrees of temperature.

Between 1860 and 1870 came the commercial introduction of bessemer and open hearth processes of manufacture, with the consequence that there was placed on the market a new form of iron which was different from cast iron by its possessing the quality of malleableness at all ranges of temperature. and from steel by its lack of the hardening power. It was really a wrought iron according to the classification then in vogue, but was distinguished from the ordinary wrought iron mainly by its freedom from slag and by its more homogeneous character. As a more perfect material of construction it was, therefore, entitled to be sold at a higher price than the wrought iron to which the trade was accustomed, and as the name steel meant in men's minds a superior material to be sold at a higher price, the manufacturers of this new low carbon iron made by the bessemer or open hearth process annexed the name steel for their new product and have been able ever since to maintain their usurpation in England and in the United States.

Professor Henry M. Howe in the tenth edition of the Encyclopaedia Britannica recognized two classes of finished iron and steel, one containing slag and the other practically slag free, and the table showing the various subdivisions and varieties reappears in the eleventh edition of the Encyclopaedia Britannica which is just being issued from the press. Professor Howe has discussed the subject of nomenclature quite fully in the issues of the Engineering and Mining Journal for February 11th and 18th, 1911, to which the attention of the members of the Society may very properly be directed. After long deliberation on the subject with a view to arriving at a real distinction between steel and iron he comes to the conclusion that the only thing which all steels have in common is that they are malleable at some one temperature, but that it is mere luck which has prevented some inventor from attaching the name steel to an alloy of iron brittle at all temperatures.

The historic or pre-bessemer classification of iron, that is to say, the classification which lies back of publications issued previous to 1860, is shown in Table I taken from page 328 of the Engineering and Mining Journal of February 11th, from which it will be noted that wrought iron was distinguished from steel purely on the basis of the carbon content. The fact that the product contained or did not contain slag seems to have no bearing whatever on the practice.

Genus	Species	Varieties
Iron	(*1*) Wrought (or malleable) iron; (*a*) iron because not steel, because not hardenable, because deficient in carbon. (*b*) wrought, because brought to shape by working, because malleable.	
	(*2*) Steel, containing enough carbon to harden on rapid cooling yet not enough to make it unmalleable when cooled slowly.	(*1*) "Cast steel," excelling because freed from slag by being melted, "cast" as indicative of this melting. (*2*) Other steel, injured by the presence of inclosed slag. (Blister steel, puddled steel, natural steel, etc.)
	(*3*) Cast iron, (*a*) iron because not steel, because not malleable, because of its excess of carbon; (*b*) cast, because necessarily brought to shape by casting.	(*a*) Gray. (*b*) White. (*c*) Mottled.

Table 1. Historic or Pre-Bessemer Classification of Iron.

The American Institute of Mining Engineers endeavored to correct the confusion which existed, owing to the usurpation of the name steel for a low carbon iron by the inventors of the bessemer and open hearth processes, and proposed that all irons be divided into two classes and be distinguished on the basis of whether they were cast when melted into a malleable mass or aggregated from pasty particles without fusion. In the classification proposed by the Committee of this Institute in 1876 the distinction between iron and steel was drawn on the basis of the pre-bessemer classification, iron being used to designate those grades which could not be hardened by sudden cooling, while steel covered those grades of malleable iron which could be so hardened. This attempt at reform failed, chiefly for the

reason that while it did conform in a general way to the evolution of the manufacture of iron and steel products, it did not appeal to the practical man because it put mild steel in the class with wrought iron.

It is interesting to note, however, that while this classification failed absolutely in the United States, German practice at least is in line with the history of the manufacture, and, therefore, preserves to a very great degree the time-honored distinction between iron and steel and in so far German practice is in accordance with the real facts in the case. It may be interesting to set down the current German practice in this respect as reflected in the well known engineers' hand book Hutte, the data given below being translated and abstracted from the 20th edition printed in Berlin in 1908, page 519:

"According to its method of manufacture, kind of use and carbon content, iron is divided into:

1. Pig Iron (Roheisen). Easily fusible but not malleable. The product of the blast furnace with 6 to 2.3 percent carbon content. Sub-divided into:

a. Gray iron for foundry purposes which is very liquid at 1200 to 1300 deg. cent., expands on solidification, fills the forms well and sharply and because of its softness is easy to work with file and chisel. Carbon, in part, chemically combined, in part graphitic.

b. White pig iron used in the puddling, Bessemer, Thomas and Martin processes. Viscous at 1100 to 1200 deg. cent., crystalline in fracture, brittle and hard. Carbon chemically combined.

c. Mottled pig iron mixed from gray and white pig iron.

d. Spiegeleisen, an iron alloy with 10 to 20 percent manganese.

e. Ferro-manganese, an iron alloy with 25 to 70 percent manganese.

2. Cast Iron (Gusseisen). With less than 6 percent carbon content. Iron remelted in the cupola, reverberatory or crucible furnace from gray (soft) or mottled (hard) pig iron, and further sub-divided, according to mode of use, into hearth or flask castings, dry sand, loam or sand castings, chilled cast-

ings (made in iron forms), steel castings (made with the addition of steel scrap), malleable castings (made with subsequent annealing in contract with ores rich in oxygen).

The following kinds of iron, No. 3 to No. 6, with 1.6 percent of carbon or less, have the common name, malleable iron.

3. Weld Iron (Schweisseisen). Iron which is weldable and malleable, capable of hardening only to a small degree and obtained in a pasty condition by puddling from pig iron on hearths (hearth puddling process) or in heating furnaces (puddling process). Carbon content 0.5 to 0.1 percent. Melting point 1500 to 1600 deg. cent. Sub-divided into:

a. Fibrous weld iron with lesser carbon content and dead gray, hooked or long fibrous fracture.

b. Fine grained iron (steely iron) with greater carbon content and light gray fine grained fracture.

c. Refined weld iron outwardly steelized by long annealing with substances rich in carbon (cementation).

4. Ingot Iron (Flusseisen). Weldable and malleable but not capable of hardening. Obtained in a fluid state as Bessemer, Thomas or Martin ingot iron in the form of blocks (ingots). Carbon content 0.25 to 0.05 percent. Melting point 1350 to 1450 deg. cent. Fracture light gray, uniformly fine grained. Elasticity higher than that of weld iron. Cast in finished form as ingot iron castings. Other uses, same as weld iron, which has almost entirely been superseded as a material of construction by ingot iron. Ingot iron and weld iron have the common name, wrought iron.

5. Weld Steel (Schweissstahl). Weldable and malleable and capable of being hardened (like weld iron). Obtained in a pasty condition from pig iron containing manganese as hearth puddled steel or puddled steel. Obtained from weld iron through long heating with bodies rich in carbon as cement steel (blister steel). Obtained from this through further treatment (fagotting) as shear or refined steel. Carbon content 1.6 to 0.5 percent. Melting point 1300 to 1400 deg. cent. Fracture, on sudden cooling, fine grained, hard and brittle. On subsequent heating of weld steel there re-appear with increasing temperatures the toughness and softness possessed before

hardening. On cooling the following temperature colors appear:

Heating to	220	deg.	—pale yellow.
"	232	"	—straw yellow.
"	243	"	—golden yellow.
"	250	"	—purple.
"	266	"	—violet.
"	278	"	—dark purple.
"	293	"	—light blue.
"	316	"	—dark blue.

6. Ingot Steel (Flussstahl). Malleable, weldable with difficulty, capable of hardening. Obtained in a fluid condition as Crucible, Bessemer, Thomas or Martin steel in the form of ingot steel blooms. Carbon content 1.6 to 0.25 percent. Melting point 1300 to 1400 deg. cent. Fracture, dead gray, uniformly fine grained, denser than the other kinds of iron. Used for the better class of tools only in the form of crucible steel and tungsten steel. Boundary between ingot steel and ingot iron at 5 000 kilograms per sq. c. m. (71 114 lb. per sq. in.)

Weld steel and ingot steel have the common designation Steel. The earlier name, cast steel, has been replaced by crucible steel. Cast steel castings are produced in finished form by casting from ingot steel (called steel castings or, better, ingot iron castings).

Heating colors (color temperatures) of steel, according to LeChatelier:

Heating to	532	deg.	—dark red.
"	565	"	—blood red.
"	636	"	—dark cherry red.
"	677	"	—medium cherry red.
"	746	"	—cherry red (full red).
"	843	"	—light cherry red.
"	899	"	—orange.
"	941	"	—light orange.
"	966	"	—yellow.
"	1079	"	—light yellow.
"	1204	"	—white hot.

In the case of weld iron, these colors first appear at higher temperatures, and in the case of gray pig iron still later."

That grade of steel which we call structural and which is used ordinarily in building and bridge construction the Germans call ingot iron (flusseisen). Ingot iron is used exclusively in Germany in rolling girder material. Other sections as angles, tees, zees, beams, channels, bulb beams, bulb angles, star sections, rounds, squares, hexagons, etc., are generally rolled in ingot iron and only on special request in weld iron. The term ingot iron in this country is generally used to describe the product of a particular rolling mill. As a matter of fact, in Germany it covers the entire line of mild or low carbon steel.

It will appear from this discussion that a present-day nomenclature to be effective must take account of the enormous expansion which has been made in the manufacture and use of steel and iron in all their forms and alloys. It should be based on the history of the subject and yet must take account of the practical every-day considerations of commercial uses, trade names, etc., and it is with an idea of getting clearly before our minds the size and scope of the subject, more than anything else, that this discussion is presented. Professor Howe, from whose publications I have drawn largely for technical information is a member of the committee appointed by the International Association for Testing Materials to work out an exact nomenclature, and we cannot better conclude our discussion or get more clearly before our minds the various classes of iron and steel than by considering carefully his latest table as reprinted from the February 11th issue of the Engineering and Mining Journal.

This table differs in some respects from that given in the supplementary volumes to the 9th edition of the Encyclopaedia Britannica, and also in the 11th edition, to both of which Professor Howe contributed the article on iron and steel. It is probable that after the electric furnace comes into extensive and commercial use, say 50 years from now, the subject will present a new phase. With that we have no immediate concern, but it does concern us today to know just exactly what we mean when we speak of steel and to recognize that the minds and thoughts of men on this subject have been powerfully influenced by the introduction of new processes and that it is ex-

Class.	Genus.		Species.	Variety.	Subvariety.
Iron	Normal or Carbon Class, owing their properties chiefly to their carbon content.	Aggregated or Weld Metal, aggregated from pasty particles without later fusion.	Wrought Iron, with Little Carbon, 0.20% or less.		Puddled Iron. Bloomery Iron. etc. etc.
			Weld (or Wrought) Steel or Blister, with more carbon, 0.20 to 2.20%.		Blister Steel or Blister. Puddled Steel (obsolescent).
		Cast or Ingot Metal, "cast" as distinguished from "aggregated." — Subgenus A: Classified by carbon content.	Steel, with either a small or an intermediate carbon content.	Low-carbon (or "Mild") Steel, with little carbon, 0.20% or less.	Bessemer Steel. Open-hearth Steel. Crucible (Mitis) Steel Electric Steel.
				Medium- and High- carbon steel, with more carbon, 0.20 to 2.20%.	Bessemer Steel. Open-hearth Steel. Crucible Steel. Electric Steel.
			Cast Iron, with much carbon, 2.20% or more.	Gray Cast Iron White Cast Iron Mottled Cast Iron	Normal White Iron. Washed Metal.
		Subgenus B: Not classified by carbon content.	Malleable or malleablized cast iron, or malleablized iron, not malleable when cast, but made malleable thereafter.	White heart. Black heart.	
	Special or Alloy Class, owing their properties to their content of an element or elements other than carbon. (Always cast.)		Special or Alloy Steels, useful immediately for engineering and like uses, or malleable.	Nickel Steel Manganese Steel. Chrome Steel. High-speed Steel. etc. etc.	
			Ferro-Alloys, useful primarily for introducing an "alloy" element or elements or not usefully malleable.	Spiegeleisen. Ferromanganese. Ferronickel. Ferrosilicon. etc. etc.	

Table 2. General Classification of Iron.

tremely hard for us to preserve in our thought on this subject the idea of a continuous evolution. We can do so, however, by remembering that the branches of the tree are borne by its trunk, and not vice versa.

In this connection I will say, as Chairman of the Structural Section, that Mr. Tiemann's paper is intended to lay a foundation for future studies along this subject and that we hope to have at some later day a paper or papers dealing specifically with structural and alloy steels and the particular fitness of these materials for specific uses. We propose other papers on blast furnace practice, rolling mill practice, etc.

Mr. Henry F. Gilg: I would be glad to make some remarks upon wrought iron for other than structural purposes based upon the salesman's point of view, leading up to some of the difficulties encountered by engineers in preparing specifications for the purchase of iron, which may open up a new line of thought on the part of consumers of that material.

The advent of the material termed soft steel and its production at decreasing costs, led some of the manufacturers to buy scrap iron in the open market in order to compete with steel at the prices that metal was establishing. This is where the first serious mistake was made, because when they were using their own scrap exclusively, they knew what they were producing; when they bought scrap outside, they did not know; for there were different grades then as well as now. Scrap has been constantly deteriorating in quality, and so have the bars made from scrap. Consumers not being familiar with the methods of iron manufacture buy material which is called "iron," wholly upon price. The result is an increased shop cost and increased maintenance. One of the methods of making iron bars is to take scrap, bring it to a welding heat, and roll it to flats by the usual means; and this is called "muck bar." There are as many kinds of this muck bar as there are varieties of scrap, so when specifications call for iron bars made of "muck bar," it means nothing, except the poorest material which can be produced. This muck bar is cut into suitable lengths, and may be formed into a pile of flats to be rolled into the finished

section; or a box may be formed of top, bottom and sides, filled with scrap and rolled out; or a piece may be used for top, another for the bottom, and flat pieces of scrap for the sides, and the box thus formed filled with scrap and rolled out. I once saw a piece of $\frac{3}{8}$ in. round bar used in an attempt to make a small hook for a platform scale without success, the material being so poor. In this instance, the consumer paid the usual labor, the price of common bar iron, etc., and did not have even scrap which he could sell or use. For this class of work the highest grade iron bars are not necessary, but a good grade may be had, and they would cost more, as a matter of course, than the common bars, but this increased cost would be more than offset by the decrease in shop cost.

A grade of iron is made by using muck bar made of pig iron, usually with the addition of some cheaper raw material, making boxes similar to those above described, and using so called No. 1 Railroad Wrought Scrap, which is supposed to be the best scrap. My observation is that there are many kinds of No. 1 Railroad Wrought Scrap. The resulting bar iron is, of course, as great in variety as the material from which it is made. While it is sometimes possible to get a fairly good grade of iron, depending largely upon the conscientiousness of the manufacturer and his good luck in his scrap purchases, the iron may be unsatisfactory nevertheless on account of the imperfect welding which may be the result of any one or more of several causes.

About thirty years ago, when wrought scrap was still good; I saw an experiment tried in a mill where I was mill clerk, for the purpose of getting a higher tensile strength. This was done by rolling a round out of the head of an old English bessemer rail, and placing pieces in the center of a pile. I will add in passing that I saw this tried last year by an engineer who is not familiar with rolling mill practice. When any of you gentlemen wish to try experiments in iron, I shall be glad to give you the names of several gentlemen who will save you time and worry.

One of the mills with which I was connected had puddling furnaces constructed somewhat differently from the one pro-

jected upon the screen during the reading of Mr. Tiemann's paper. The roof was not flat as shown in the illustration, but was curved like the roof of a bake oven, the fire chamber had a regenerative chamber, which, although not exactly like the Siemens-Martin, had somewhat the same effect, the heat being about one-third greater than in the old style puddling furnace. This furnace was designed by my old friend William Stubblebine, who spent 60 years actively in making iron. The materials used in this furnace were cast iron borings and steel turnings. In hundreds of tests of one inch rounds, including experimental bars of all kinds of proportions of materials, not one bar fell below 48 000 lb. tensile strength and only one bar showed less than 20 percent elongation in 8 in. the elongation being 19 percent, up to 34 percent was not uncommon. One day while $1\frac{1}{2}$ in. by $\frac{3}{8}$ in. bars were being rolled on the puddle mill direct from the puddled ball, a piece got into the collar of the rolls accidently, and resulted in a bar a little over 2 in. wide, about $\frac{3}{16}$ in. thick, and 201 ft. long. Some of my friends who have 35 to 45 years rolling mill experience still doubt my statement. While the material used here was scrap, it was selected and of uniform quality; and an excellent grade of iron was the result. This iron was much superior to the bars from wrought scrap, but, of course, not the equal of bars from all pig iron of the right quality, properly worked.

My observation extending over many years makes me believe that the good old fashioned wrought iron, made wholly from pig iron, properly worked, will be increasingly used for some purposes by discarding the substitutes of cheaper grades of iron and of soft steel, notwithstanding the statements I have heard, as far back as November 1875, when, while visiting the Edgar Thomson Steel Works, I was told I had seen the last of the puddling furnace.

I have never seen any specifications for bar iron which could not be met by any one of the above ways of making iron, except those of the United States Navy for iron for chain cables. The physical specifications are 48 000 to 52 000 lb. tensile strength; elastic limit 60 percent of the tensile; elongation not less than 30 percent and reduction not less than 50

percent in 8 in.; chemical specifications, carbon not over .06; phosphorus .04 to .10; sum of carbon and phosphorus not to exceed .15; manganese and silicon not to exceed .10 in either case, and sulphur not over .01. As a matter of interest, I will mention that the mill with which I am connected made links of three inch rounds for chain cables, the bars being tested, full size, by a government inspector; one bar showed 37½ percent and another 42 percent elongation in 8 in., all other requirements being met. The finished links are required to stand a pull of 525 000 lb. A number of links tested at the Charleston Navy Yard pulled from 625 000 to 640 000 lb., a casting finally breaking at 632 000 lb., without sign of fracture in the link in the testing machine at the time. The bars for the links were scarfed by cold sawing, formed into links, with one heat only, in a machine on the order of a bulldozer.

Large industrial plants and railroad systems must have engineers to prepare specifications for iron for various purposes, so the consumer may get material which will answer the purpose for which it is intended; they must have purchasing departments to buy the iron, and the cheapest iron which will meet the specifications is bought as a matter of course. In answer to the question "How about inspection?" I will say that I have seen iron rejected on inspection and accepted by the same inspector upon a subsequent requisition for iron of the same section. Rolling mills which make the cheap grades of iron do not take rejected material to the dump; if it is worked over, as may sometimes be the case, it is no better than it was originally. Good material may be reworked a certain number of times. It becomes a difficult task, therefore, for the engineer to provide specifications which will make the manufacturer be honest. A known quality of puddled pig iron bar, made in different mills, will show 48 000 lb. to 52 000 lbs. tensile strength and an elongation of 25 percent in 8 in. Several months ago an engineer prepared specifications for minimum of 50 000 lb. tensile strength and 27 percent elongation in 8 in. The probabilities are that this gentleman will get something besides properly worked pig iron bar. He should have made the minimum tensile strength 48 000 lb.

If a purchasing agent buys the best material to the specifications he is suspected of irregularity. The purchase of the cheapest materials to specifications has been the cause of greatly increased shop cost and maintenance, so much so, that the mechanical departments of three large railroads within my knowledge have been studying the problem for several years with a view of getting the proper kind of iron for their purposes. This will be difficult under the present system, and I will illustrate with an example. A railroad had been buying iron as cheaply as possible to its specifications, the purchasing agent telling me a number of times that he would buy the cheapest he could get, it being up to the mechanical department to make their specifications more rigid if they required better material. Last year this road concluded to try better iron and paid twice as much as formerly. They bought at the wrong place, getting bars rolled from iron car axles. I have seen some iron (?) car axles which have caused wrecks by breaking in service. My remarks under the methods of manufacture will apply to car axles, so you will understand why the railroad continued to have its troubles. Pittsburgh mills could have furnished guaranteed all pig iron stock at about $5.00 a ton less than the railroad paid for the kind of bars it received.

Staybolt iron for boilers, which cannot be made too good, is open to the same criticism, some being made wholly from scrap. A railroad paid 40 percent less for iron to specifications on part of its system than it did on a division where no attention was paid to the specifications of the road, quality alone being considered. The latter division's expense for staybolt maintenance was something over a dollar less per boiler per year than it was on the other part of the system.

The same difficulties obtain in crane and sling chains. The factor of safety in such chains cannot be too great, and only the very best material, properly worked, should be considered; the pile should be made of billets uniform in length with the pile, so there is absolute certainty of good welding in the rolling process. Iron to the U. S. Navy specifications for chain cables will stand two or more times as many vibrations as a fagot bar of selected scrap; it will stand 50 percent more vi-

brations than four of the best known brands of staybolt iron, all of which were slab-piled. I do not think it will be very long until some of the States have inspectors for chains similar to those whose duty it is to examine locomotive staybolts.

Several years ago I showed some samples of fractured bar iron to a purchasing agent, who told me that "We don't use pig iron!" When I called at the same place a year or two later, a practical man who was superintendent, and who had done the buying before the purchasing agent was installed, told me the purchasing agent was dropped and he himself was compelled to look after the purchases in order to get the proper quality of materials, because there was danger of the company losing its reputation for high grade work. He divided his labors by putting a competent young man as assistant in the manufacturing department. I mention this extreme case to emphasize the idea I wish to convey, that if price is to govern the purchase, the specifications must be made sufficiently rigid to compel the purchase of the right kind of materials for the purpose for which they are intended; and this can be done only by having a knowledge of the methods of manufacture. Some engineers whose duty it is to prepare specifications for a better grade of iron are afraid to make them rigid, fearing either that there will be no competition, or very little, or that the prices will be so high as to call for censure from superiors. If the specifications for iron are made very rigid, one mill may enjoy the business at a high price for a time, but it will not be very long until other manufacturers become aware of the "good thing," and will create competition which will lower the prices. I regret that I am not at liberty to give the particulars of a little monopoly which would illustrate this.

Mr. Jas. H. Baker: It may be out of order to speak on a point or two not referred to in the paper before the meeting. But some things have come up in the discussion on which a word or two might be of interest. In the matter of iron making it may interest my young friends to have a description of what I saw in this line 53 years ago in the mountains of Virginia. I would take my father's team and go to an iron works and wait all day while the forge made for us probably a ton of wrought

iron from the pig. I am not an illustrator, but the accompanying rough sketch, Fig. 1., will show you how we obtained the blast to blow the open hearth fire in which the pig iron was melted down, refined, forged into a bloom, reheated and forged into bar iron. A fall of water of say 15 ft. was secured and after falling some four or five feet to acquire velocity it entered an upright box or hollow log, the lower end of which was inserted in a horizontal box and at the opposite end of this last and on the lower side was a hole to let the water out while the air carried in all the falling water escaped from the top of the box through another vertical log or box and was carried to the forge.

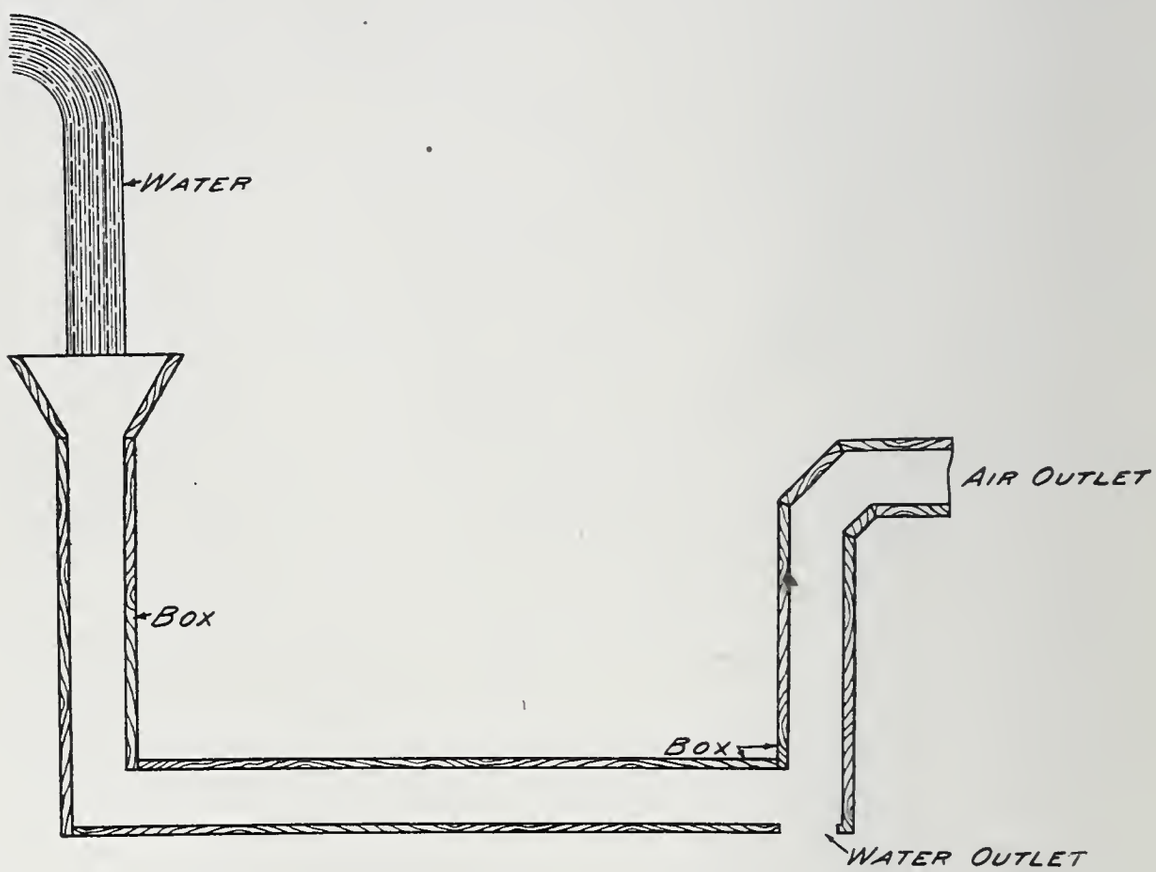

Fig 1. Early device for securing blast pressures.

The hammer was run by tups fastened in the wooden shaft of an overshot water wheel, while the spring to give the hammer force was made of dry hickory wood. There were only two sizes of iron given out to iron wagons with, and from these we made all the small forgings as well as the large ones.

Referring to the remarks of Mr. Gilg concerning the relative value of iron made from all-pig and that from scrap or a mixture of scrap with muck bar, I will say that 25 years ago

horse shoes were imported from Germany, because no steel calks were used on them, and from these shoes was made supposedly the most reliable chain iron. But, having taken a large order for two-inch high class naval chain, the mill manager of whom we obtained our supplies, asserted with confidence that the iron made solely from pig iron by the usual process of puddling and re-rolling would be as good and far more uniform. The material for this chain was made in that way and it cleared, to my mind once for all that the way to get the best was to have it made in this way. Of course, different pig irons would be used for different purposes and care taken in its selection. So that I can fully endorse what the gentleman has said on this point.

Some one has asked about heat treatment. Let me say that fundamentally this is one of the simplest of matters, the principles of which have been practised, if not always understood, from time immemorial. If you properly heat a piece of steel and could then cool it in the snap of a finger it would practically have no grain, in other words it would be refined in its physical structure to the greatest degree. The real demand for skill and knowledge in the matter comes in choosing the proper heats, the allowable rate of cooling, the amount of re-heating in the way of tempering or modifying, in connection with the size and shape and kind of steel in the article. If you care to know what I think about this matter more in detail I respectfully refer you to an article in the American Machinist of January 5th, 1911.

THE ELECTROMETALLURGICAL REVOLUTION IN THE IRON AND STEEL INDUSTRY OF NORWAY AND SWEDEN

By Jos. W. Richards*

About a year ago the speaker had the pleasure of addressing a Pittsburgh audience in connection with a meeting of the American Electrochemical Society, on "What Electrochemistry Is Accomplishing," and in it went over the list of the various things which were being done along electrochemical and electrometallurgical lines. Since last spring the speaker visited Sweden and Norway, inspecting some of the new electric furnaces there, and thought that tonight you would be interested in a talk on one special branch of electrometallurgical work. The metallurgy of iron was found to be in such a state of transition that the visit was unsatisfactory and arrangements were made to go over again this coming summer in order to see these furnaces working. Last year there were a number of furnaces under construction, but only one was seen in actual operation; the rest of them, they said, would be in operation during the winter and spring of 1911, and they are fulfilling their predictions.

Speaking first of the general conditions in Norway and Sweden. Those two countries are very similar to Canada in their geology and natural resources. They have plenty of running water and waterfalls, and very little or no fuel. They also have plenty of good, pure iron ores. You all know that the iron industry of Sweden is practically the best developed of the iron industries, as to quality, that there is in the world. The Swedes are the iron metallurgists of the world *par excellence*. Their great iron society, the Jern Kontoret, is something which I think it will interest you to know about. The ironmasters

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of Sweden some 150 years ago got together and formed this society, in which the members came together and exchanged information, hired experts for their common benefit, ran a bank, published a journal, and held meetings; a business, a social and a scientific society all in one. They published for a great many years the Jern Kontoret's Annaler, which contain some of the finest papers on the metallurgy of iron and steel that have ever been published, especially those of Akerman and Odelstjerna. They have a fine building in Stockholm containing offices, a library, and a bank. They have consulting metallurgists who are at the disposition of all the members of the Society, at a nominal rate. Mr. Loeffler is consulting iron metallurgist. It is a very effective organization.

When it comes to the making of electric-furnace pig-iron, the development is slightly different in Sweden than it is in Norway. In Sweden they have a great deal of water, large rivers with some small "Niagaras." One of the largest falls in Sweden is the Trollhattan, fed by Lake Venern, which is about 30 mi. wide and 60 mi. long. A very large volume of water falls about 80 ft. in running out of the lake, in a distance of about one mile. It is estimated that this fall represents a minimum of 150 000 h. p., and in flood about 300 000 h. p. They are going to regulate the lake so as to get about 250 000 h. p., all the year round. The government has taken over all the water-power in Sweden and declared it to be government property, and is developing this Trollhattan power.

The latter is close to a well-populated part of the country. Not more than 50 mi. away is Gothenburg, the largest port in Sweden, and within 50 or 100 mi. of Trollhattan there are several cities which are getting all their power for lighting and traction purposes from the Trollhattan region.

The government has now developed at Trollhattan 80 000 h. p., the electrical units being 10 000 h. p. each. The buildings remind one very much of the Niagara Power Company buildings; it is altogether an extremely modern plant, and very well built. They are selling this power at Trollhattan for $12.50 per h. p. year, which is the price which the government makes to

all who are using it there, and yet this is the most expensive water-power in Sweden.

There are other water-powers which are a little more removed from the centers of population, those, for instance, up along Lake Venern, upon some of the streams flowing into it. One of these is at Gullspang, where there is 20 000 to 30 000 h. p. That power costs about $10 per h. p. year. If you go farther north, up into the Northland, as they call it, you find large streams and large waterfalls aggregating several hundred thousand horsepower, which are not utilized at all and where there is practically no population. There are fine beds of iron ore in that vicinity and plenty of wood for charcoal. The government is also taking hold in this region, for instance near the large Kiruvana Iron Mines, where it will develop a large fall of about 100 000 h. p. This power will be used to electrify the railroads which bring the ore to the seaboard, and also in part for smelting the ore in electric furnaces. In the Northland such powers can be obtained, developed and run at a minimum cost of about $7.50 per h. p. year, which is analogous to some of the large water-powers in the province of Quebec, Canada.

In Norway the conditions are somewhat different. There is a range of mountains running parallel to the coast, at a distance of about 50 mi., always capped with snow, and these give a very steady supply of water all the year round. In the valleys on the table lands there are some large lakes mostly glacial in origin, which serve as natural reservoirs, and in many cases there is very little development necessary—very small dams to build or artificial lakes to make to regulate the supply. The streams are regulated by the melting snow and the natural lakes, so that nature has made the equipment almost ideal for water-power purposes. Then the heights are very great. There are places where the fiords run in as narrow bays from the sea right up to the base of the mountains, and within a distance of one or two miles you can get from 1500 to 2500 ft. fall. A very small amount of water coming down that height gives a large amount of power, very cheap to develop electrically. The water from these lakes is clear and free from grit, and therefore can be used in Pelton water-wheels without cutting away

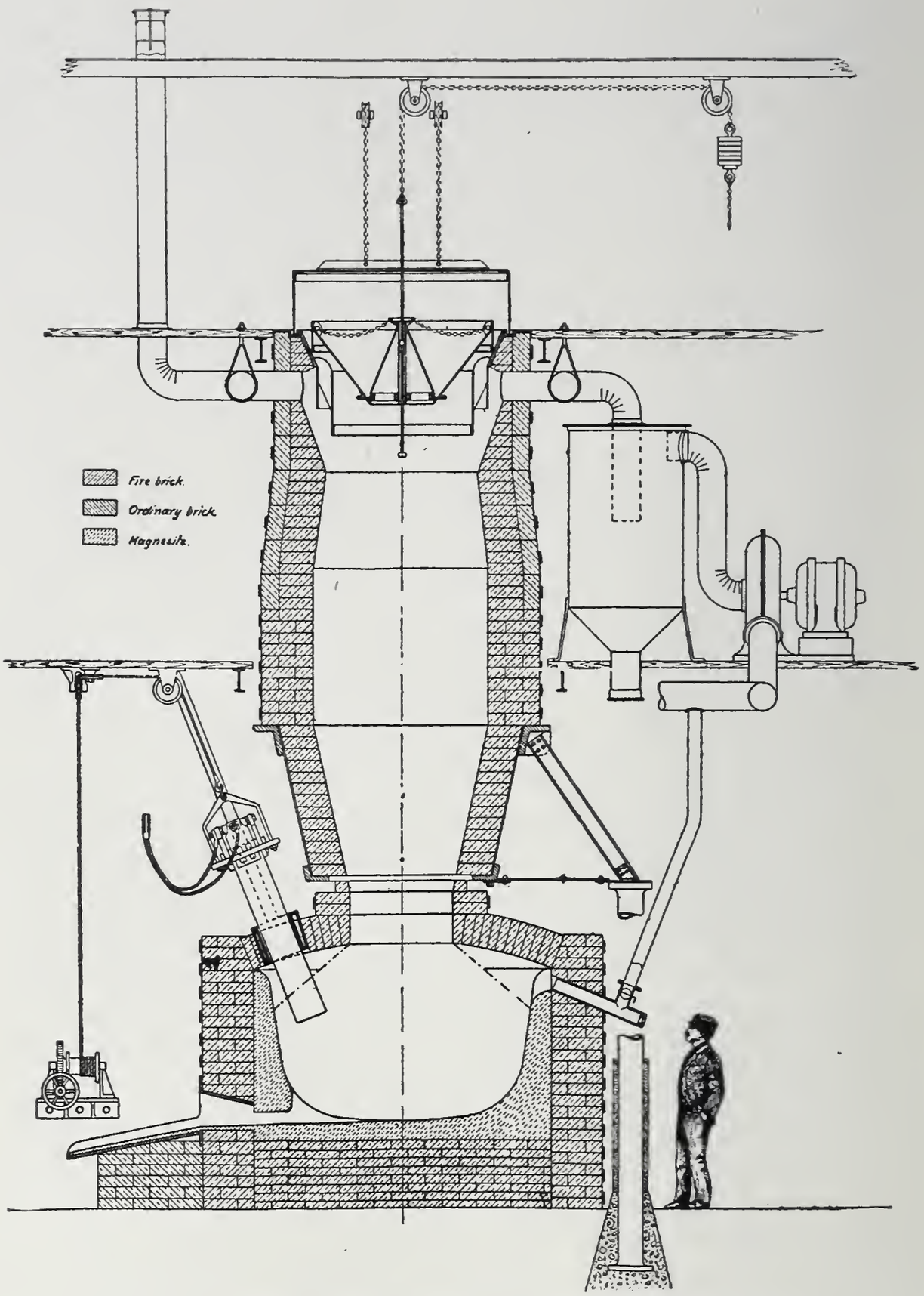

Fig. 1. Swedish Electric Pig Iron Shaft Furnace.

the metal parts. So the conditions are almost ideal for cheap development of power, in a different way than in Sweden. Many of the powers in Norway can be had up to 40 000 and 50 000 h. p. and there are numbers of them along the interior of the fiords where the total hydraulic and electrical plant would not cost over $25 to $30 per horse-power and where the total cost of producing the current is about $5 to $6 per h. p. year. There is a water-power company which is selling electrical power in Norway at $6.60 per h. p. year and making a profit on it. The cheapest the speaker knows of is a small plant of 1 000 h. p.,

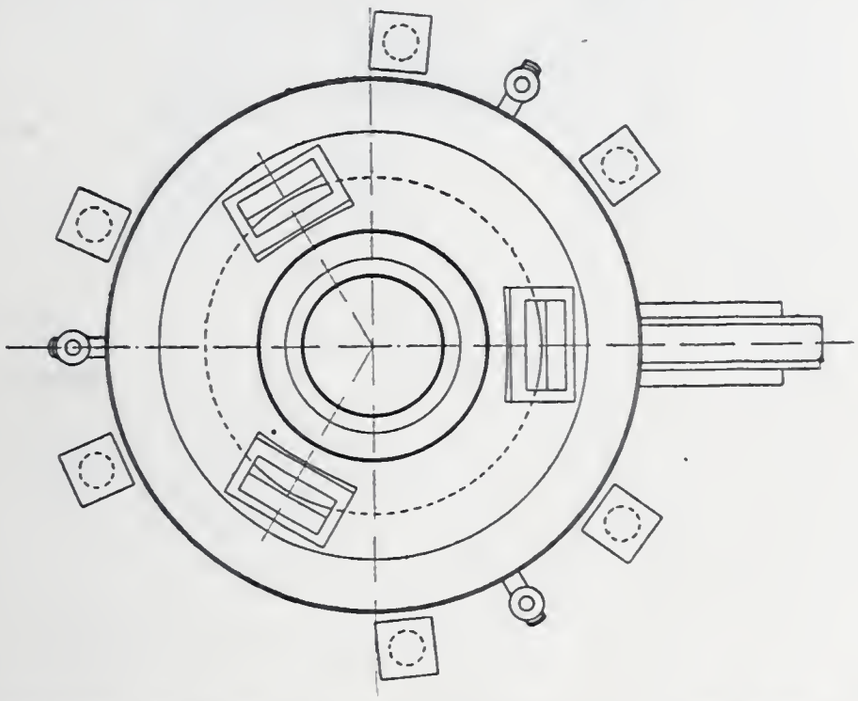

Fig. 2. Swedish Electric Pig-Iron Furnace. Plan with Shaft and Electrodes Removed.

down near the southwest corner of Norway, with a fall of 400 ft., which has been in operation two years; counting all expenses, depreciation, interest and labor, the total cost was 15 kroner per h. p. year, which would be about $3.85. It is amazing what you can do with electric current that cheap. At that price it is cheaper to heat your house with electric current than it is to burn coal, and the Norwegians are waking up to the fact that electric current is cheaper than coal for a great many purposes besides metallurgical operations.

The industries the speaker desires to speak about particularly are the iron and steel industries, for which Sweden and Norway, particularly Sweden, are famed. For several hundred

years they have been making in Sweden the purest iron made in the world. It was originally made and forged directly from very pure ore. When you reduce the ore directly in a forge, the reducing influences are so weak that you do not reduce the impurities, you reduce only some of the iron oxide, and leave a great deal of it unreduced. That is the price of getting iron

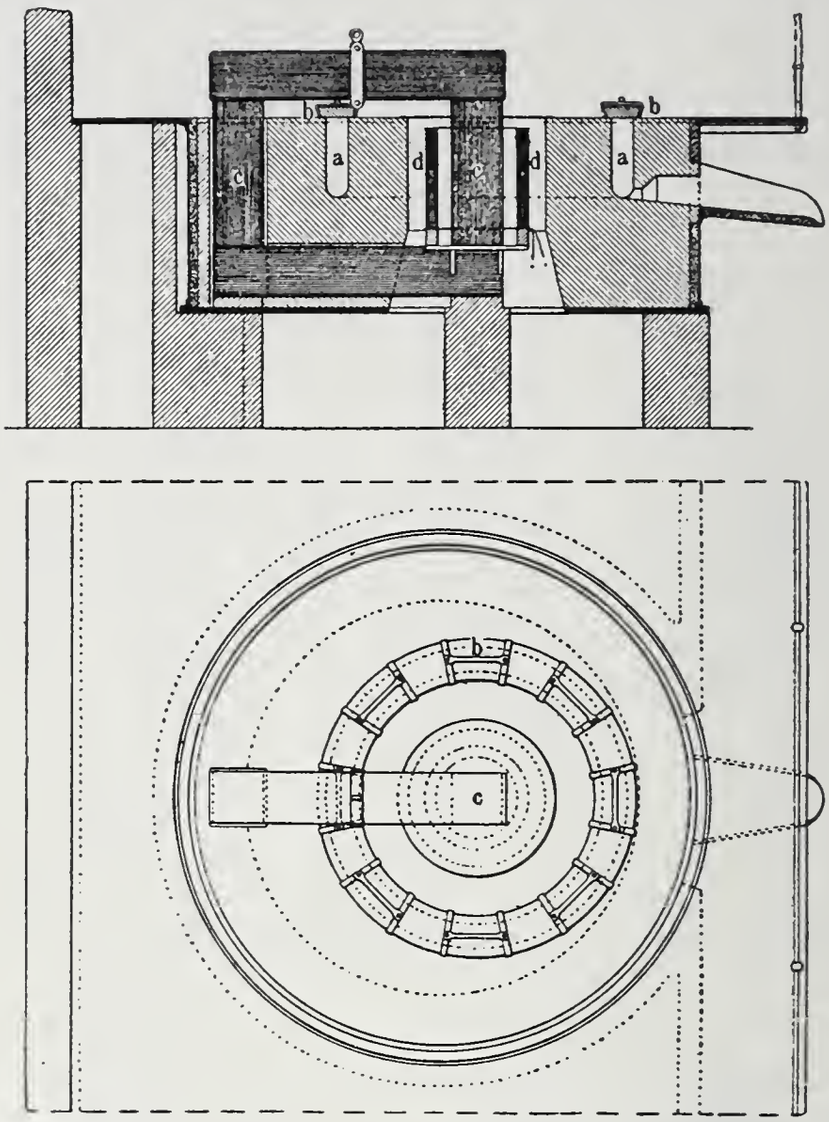

Fig. 3. Plan and Elevation of the Original Kjellin Induction Furnace.

very pure. If you try to get all the iron out of ore you get with it a great many other impurities which you do not want. Another reason for the purity of this iron is that they have no fuel except charcoal, so that even when they started blast furnaces all the pig-iron was made by means of charcoal, and its freedom from sulphur and phosphorus was the basis of the purity of the famous Swedish charcoal iron.

The situation which now faces the Scandinavians is this:

Within the last ten years the price of charcoal has doubled. The reason has been chiefly the increase in the use of wood for making paper. Wood is more valuable for making wood-pulp for paper than for making charcoal; it is even more valuable than for making match-sticks. I was travelling through their magnificent forests, and said to a Swede with me, "Is this the kind of wood you cut down to make Swedish matches?" He said, "We do not make matches out of this, we make paper out of it." I said, "Where do you get the wood you make matches out of?" "Oh," he said, "that comes from Russia." It is more profitable for them to float cheap match-wood across the Baltic Sea from Lithuania, and turn their own wood into paper-pulp. So the price of charcoal has gone up from about $5 a ton to about $10, and the consequence is that the famous Swedish iron threatens to become a thing of the past because they have not the charcoal to make it with. There is some wood that is not fit for paper-pulp, and thus there is a limited supply of wood for charcoal which cannot be used for other purposes. That amounts to about 300 000 tons of charcoal a year, and this limited quantity used in blast furnaces would make about 300 000 tons of pig-iron a year, and no more. In a famous iron plant which I visited, at Domnarfvet, there were four blast furnaces and only one of them was on charcoal; the other three were running with coke brought over from England. That is merely a temporary expedient. For what advantage have you, using the finest ore in the world, if you smelt it with common coke that brings sulphur and phosphorous into the furnace?

It is exactly at that difficult point that the electric pig-iron furnace, shown in Figs. 1 and 2, comes in and offers a solution of the problem. The solution is this: A lower grade of charcoal can be used in the electric shaft furnace than you can use in the blast furnace. You do not have to force blast through it, and it does not have to be so strong as regards crushing strength; you can use charcoal almost in the form of "breeze." Secondly, you only need a third as much fuel to make a ton of pig-iron, or with a given amount of charcoal you can make three times as much pig-iron from it in the electric furnace as in the blast furnace. The reason is this: In the blast furnace you use about two

thirds of the fuel to get the smelting heat necessary to melt down the iron and the slag, and only the other third is used for chemically reducing the ore; in the electric shaft furnace you replace this two-thirds of the fuel by the heat of the electric current. As a measure of national economy that is a very great advantage, for it enables Sweden to make three times as much charcoal pig-iron as it otherwise could. In the third place it has been figured out

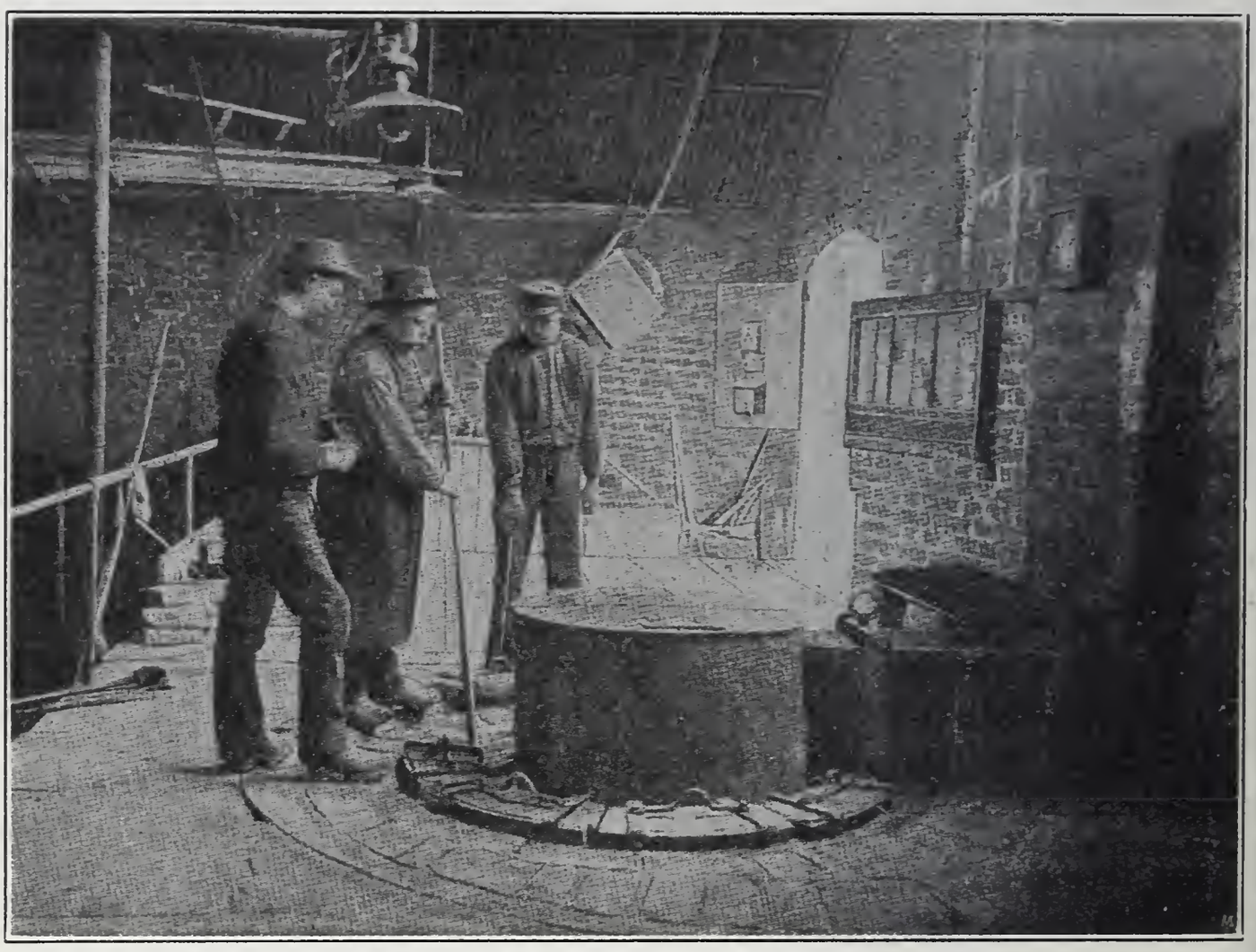

Fig. 4. Top View of Kjellin Induction Furnace.

that with power at about $8 per h. p. year, such as can be had in the northern part of the country close to the greatest iron mines, pig-iron can be made $2 a ton cheaper in the electric furnace than in their blast furnaces. There is no doubt about this. The Swedes are making pig-iron *now* in their electric furnaces cheaper than in their blast furnaces. There is still another advantage, and that is that the pig-iron made in the electric shaft furnace without any air-blast is probably superior

in quality to the pig-iron made by the blast furnace with an air-blast. As you know, for every ton of pig-iron made there are five tons of air blown into the blast furnace, about one ton of oxygen and four of nitrogen, and these saturate the pig-iron with all the gases it can possibly take up. These have their deleterious effects upon the pig-iron. They do not show up so badly when you make Bessemer steel; they show up a little more when you make open-hearth steel; but when you come to make fine steel, where every little item counts, then the oxygen and nitrogen taken up in the blast furnace from the blast count very decidedly in the quality of the steel which can be obtained from the pig-iron. Swedish steel-makers now say that the pig-iron made from the electric furnace is superior to the pig-iron made in the blast furnace, for the making of fine steel. They cannot well put the difference into words, but simply say that after making it into steel, annealing, hardening and putting an edge on it in just the same way as their older material, it is superor in its useful qualities.

I will now describe the rise of the electric-furnace pig-iron industry, as far as I know it. There were some young men at Ludvika in Sweden, one named Groenwall, one Lindblad, and one Stahlhane, and they interested the influential copper-works people at Falun, the oldest copper mine in the world. These latter had plenty of capital, and were willing to back these young men who thought they could make electric-furnace pig-iron. So, having the financial backing of Mr. Lundberg and some others of the capitalists of the "Stora Kopperbergs Aktiebolaget," they started in to see what they could do. They tried several types of furnace, the first one used being about like a ferro-silicon furnace—simply a square cavity with a large square electrode coming down into it. Putting the charge around the electrode, and passing the current, they melted the charge down to slag and metal. This furnace, however, did not work satisfactorily. The charge descended irregularly, it required an enormous electrode which was expensive to make and which fell to pieces, and the experiment did not turn out well. Other furnaces were tried, over $200,000 being spent in experimenting. They built four or five different patterns of furnaces, until at last they

found the kind of furnace that would work. After spending nearly a quarter of a million dollars, and working two or three years at it against great discouragement, they found a type of furnace which would make pig-iron successfully and they put it in operation. They designed it for 1500 horse-power, put it up at the Domnarfvet Works, and started it in December, 1907. They did not have the power they wanted, as it was in the

Fig. 5. Tapping Steel from Kjellin Induction Furnace into Molds.

middle of winter, and instead of having 1500 h. p. they had only 600 to 700 at the most. I would like to impress upon you the difference between running a furnace at full capacity and running it at half capacity. If you take a blast furnace designed to make 200 tons a day and run it at 100 tons a day you know the difference in the economy of running that furnace. Your radiation losses and a good many others would be almost exactly as great for 100 as for 200 tons, and the fuel consumption and

other costs would go up. They were running this furnace at less than half its proper capacity, and yet after three or four months' work they came to the conclusion that they could make pig-iron in *that* furnace under *those* conditions cheaper than in the blast furnaces alongside of it. You will find an account of the first running of that furnace in a report of the Canadian Commission by Dr. Haanel of Ottawa and in a paper by him published in the Transactions of the American Electrochemical Society, May, 1908.

That was success enough to induce these pioneers to try a larger furnace. But they were near to the end of their funds. They succeeded then in interesting the Jern Kontoret, and this society agreed to take over their patents, put up a larger furnace, run it, and develop the whole project. So as it stands today the Jern Kontoret, the ironmasters' association of Sweden, has taken the patents of Gronwall, Lindblad and Stahlane, and has agreed to spend $100 000 in further experiments. This society has put up at Trollhattan a furnace 50 feet high with a total capacity of 3000 kw., or 4000 h. p. In order to support the furnace, and not to have the weight of the shaft on the crucible arch, the whole shaft of the furnace is supported by girders resting on the side-walls of the building. The weight of the furnace and charge is 200 tons. When I was there in August, 1910, the furnace shaft was hanging about seven feet from the ground, all beneath being clear. That enables the operators to build the crucible beneath just as they please. They can put in the electrodes where they please, or take the crucible away and build another, without being hindered by the usual arches or pillars supporting the shaft of the furnace. The furnace is being run by the chief metallurgist of the Jern Kontoret, Mr. Loeffler, with the assistance of four or five other technical men. They have a fine chemical laboratory, physical testing laboratory, and the government has given them power practically free for two years. The government cannot give it to them for nothing, but sells it to them at the nominal sum of $1 per h. p. year.

The furnace was started in November, 1910. The current being turned on, they had pig-iron out of it in four hours, and several thousand tons of pig-iron have been produced in it

already. They have been experimenting with different ores from different parts of Sweden, different charcoals, and different ways of running the furnace. They have used four electrodes, and then three with a three-phase system, and then six with two three-phase systems, to determine which is the best commercial type of electrical current to use. They anticipated trouble with the regulating of the electrodes, but after the furnace

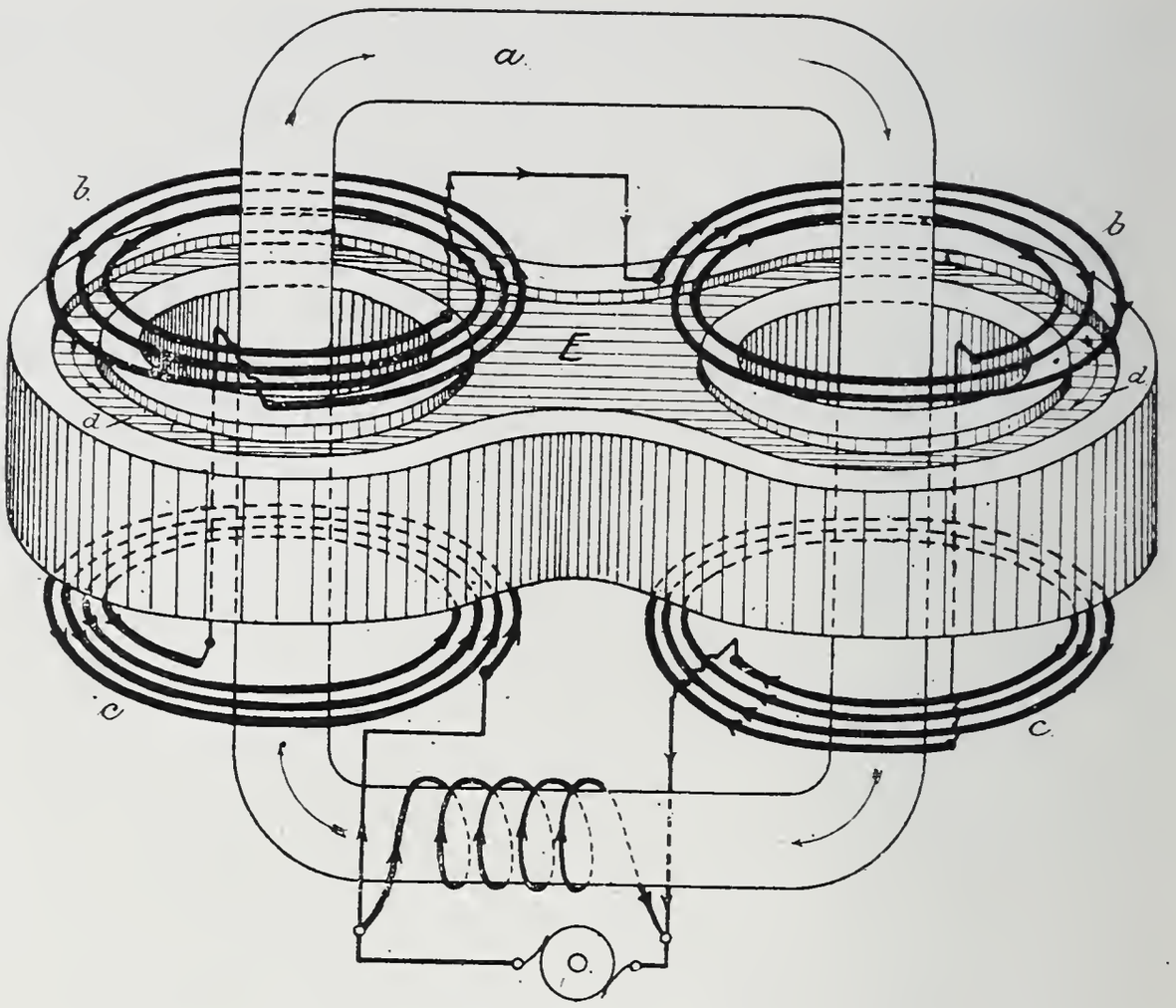

Fig. 6. Diagram of Electric Circuits in Hiorth Induction Furnace.

had been running a month, I had a letter from Mr. Loeffler in which he said: "For two weeks after we started we did not touch the electrodes to regulate them at all."

The Swedes make their own electrodes at a very fine plant at Hoganas on the Sound. I have heard it said in different parts of Europe that they are the best made in Europe. Mr. Forsell of our National Carbon Co. was over there with them for some time; perhaps that accounts for it. The electrodes used in this furnace are 13 inches square by 6 feet long, and of the ordinary

hard-baked carbon. They have devised a way of connecting the carbons together so as to avoid having to throw away the butt-ends. It used to be that the butt-ends which could not be used when they were too short constituted a waste greater than the usual actual consumption of the carbon in oxidation. It would be easy enough to connect them if they were graphite, but ordinary carbons are "different"; yet they are successfully connecting them together, and by so doing have reduced the actual consumption of carbon to about 40 percent of what it was when they had to throw away the butt-ends. I do not know how they are doing it, but we should remember that the waste of the electrodes is one of the greatest expenses in running the electric furnace, and it has been a great desiratum to find some means of connecting the ordinary carbons together and use up all the butt-ends.

As to the conditions of operation of the furnace, you must use enough carbon to reduce the ore, but that is all. You need less carbon than is necessary in the blast furnace for this reason: in the blast furnace the reduction is done mostly by carbonic oxide gas, CO, while in the electric furnace it is mostly by solid carbon. The blast furnace manager will tell you that the more ore you reduce by solid carbon the worse your blast furnace is working. In the electric furnace you reduce most of the ore, by solid carbon, but you also utilize for reduction the CO gas which is formed, and the ratio of CO_2 to CO in the issuing gas produced is better than you can get with any ordinary blast furnace. In the ordinary blast furnace two cubic feet of CO to one of CO_2 is about the normal running. In the electric furnace they are approximating the opposite; they are getting close to two cubic feet of CO_2 to one of CO. In other words they are utilizing the carbon for reduction much better than it is utilized in the blast furnace.

There is another curious thing about the running of the electric furnace. The less carbon you use, within certain limits, the more assistance you get from it, the more heat it generates in the furnace and the less current you have to use. All you have to do to choke up the furnace when it is making pig-iron is to put in too much carbon. You give it indigestion at once. The reason is this: In making a ton of pig-iron in an

electric furnace there is just a certain amount of oxygen to be removed in the furnace and no more can be had; therefore you can only oxidize by it a certain amount of carbon. If you put in the minimum amount of carbon you get CO_2, if you put in twice as much you get CO, and you develop absolutely less heat in the last case than in the first. It stands right out in the reports of the Swedes themselves. They tell you how much carbon they put in the furnace, and as they increased that amount you will find they increased the amount of current used. We had a good long discussion about that when I was in Trollhattan last year and came to the conclusion that the proper thing was to put in just the right amount of carbon to get the maximum as-

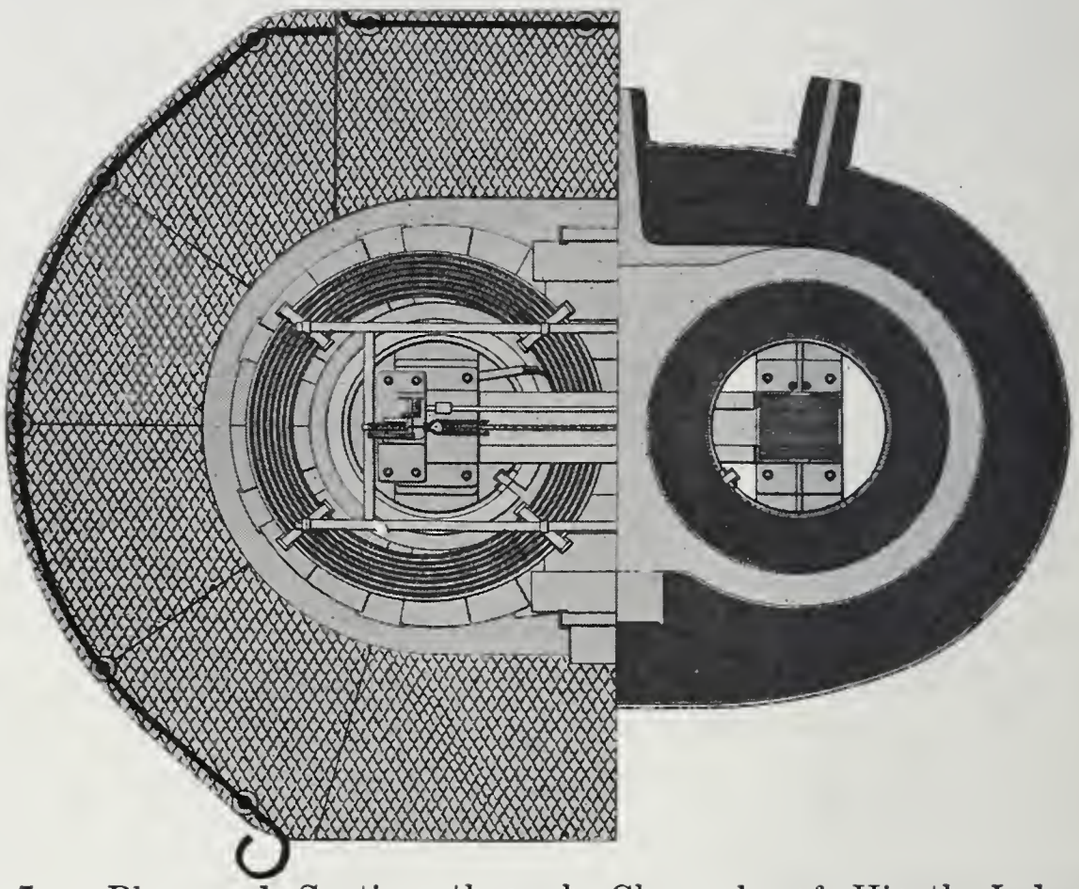

Fig. 7. Plan and Section through Channels of Hiorth Induction Furnace.

sistance from the heat of oxidation. It requires theoretically 0.22 ton of carbon to reduce a ton of pig-iron in the electric furnace. When you use charcoal, which is not pure carbon and has some moisture in it, you ought theoretically to get along with about 0.25 ton. In actual practice they are using from 0.28 to 0.30 ton of charcoal per ton of pig-iron. The average of coke used in the Pittsburgh district is probably 0.95 ton.

That is the difference in the amount of fuel required in the electric furnace and the blast furnace.

Regarding the electric power needed, when the small furnace at Domnarfvet was started and run at one-half capacity they obtained two tons of iron per horse-power-year, as their output. I had a talk with Dr. Haanel about this and he said, "Isn't it possible to do better?" I said, "Yes. I have a hobby for calculation—and I have calculated how much you ought to get. If you have a furnace of the same capacity as a small blast furnace and run it with the proper amount of current at the proper rate, as hard as a blast furnace would be run, you ought theoretically to get up to five tons of pig-iron per horse-power-year." The next question was, "What do you think we can get with this furnace if it is run up to proper capacity?' I said, "I have calculated the radiation surface, compared it with a blast furnace of the same size, and I believe you should get up to three tons per h. p. year in this furnace." They have been running it harder since and have reached 2.75 tons per h. p. year from that furnace.

But now the large furnace at Trollhattan is in operation, since last November, and it started right off giving three tons per h. p. year and has since been doing better than that. It is confidently expected that in a few months it will reach the rate of four tons. The cost for power, per ton of pig-iron, may thus be known with exactness.

The net result of these Jern Kontoret experiments at Trollhattan has been this: The society ran these experiments themselves, putting their own men in, the best metallurgists to be had in Sweden; these have been running it since November and now say the furnace is a success. They know how to treat the different ores, they know what kind of charcoal to use, they know how the furnace will run, and the Jern Kontoret has been doing this for the benefit of the iron industry all over Sweden. I asked Mr. Loeffler if he would not come over and describe to the American Electrochemical Society what they have been doing, but he said they were too busy drawing up plans and making contracts. This situation is the justification of the title of my lecture because since the great iron society of

Sweden has taken hold of this thing, and is running the furnace, and is so satisfied with the results that plans are being drawn up for electric pig-iron furnaces all over Sweden, I believe it is only a matter of a very few years before the blast furnaces of Sweden will all be shut down and electric pig-iron furnaces running in their places. I am sure Mr. Loeffler thinks so, the inventors of the furnace think so, and the Jern Kontoret thinks so. I had a visit last week from Prof. Eichoff, professor of metallurgy in the University of Berlin, and on talking the Swedish situation over I found that he thought the same way also. He said: "The electric pig-iron furnace is simply going to run out the blast furnace in Sweden. It is a certainty."

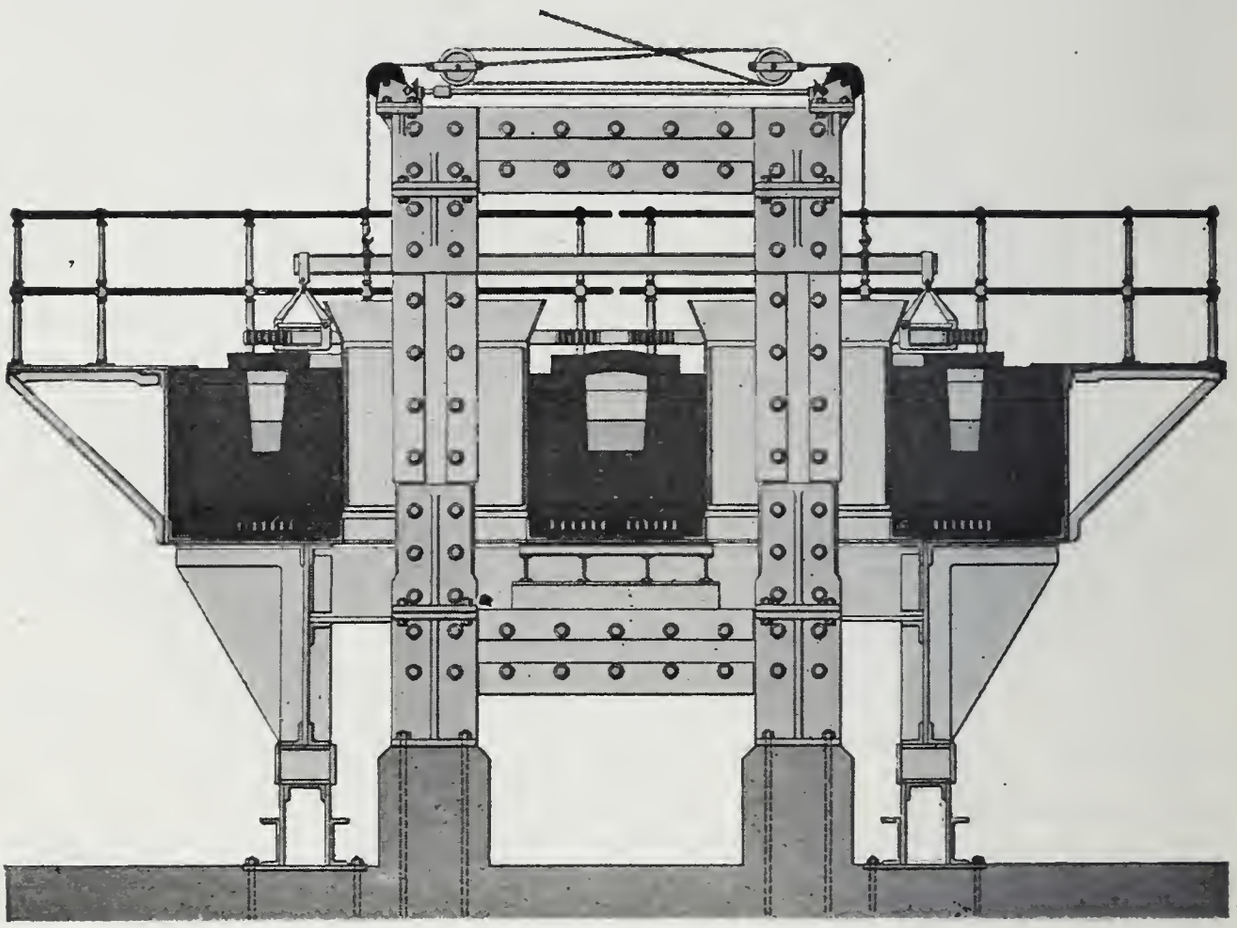

Fig. 8. Vertical Right-Left Section of Hiorth Induction Furnace.

In Norway there is not a large blast furnace industry. There are only three or four small blast furnaces in all Norway. But there is water-power in abundance, on deep-water fiords, and cheap ores. The water-powers in Sweden will average $8 to $12 per h. p. year; in Norway, from $4 to $8. The latter are mostly on deep salt water, where ocean steamers can go right up

to the works, giving shipping facilities which the Swedes do not possess. The Norwegians have as much if not more charcoal; the thing they most need is capital. That is the rub with them just now and they are very jealous about allowing other people who have the capital to come in. You can usually depend upon the farmer and fisher members of the Storthing to vote down any concession to foreign capital; they are afraid foreigners will come in and exploit their country. But I think they are fast becoming enlightened, because some foreigners have already established industries in some parts of Norway, and those sections where the electrochemical industries flourish are an object lesson in prosperity to the rest of the country. Houses, schools, roads—the whole neighborhood—have a prosperous aspect, and I think that Norwegians in general will soon recognize that it is to their benefit to let foreign capital come in under liberal yet proper concessions.

The same inventors who erected the electric pig-iron furnaces in Sweden are already putting in similar plants in Norway. Most of you have heard of the large saltpeter industries in Norway, the making of nitrates by combining electrically the constituent gases of the air. Some of the people who have made considerable money in that way have organized companies to make iron and steel electrically. They are putting up a works at one of the prettiest spots in Norway, at Odde, at the head of the Hardanger Fjord, in which they are going to make electric pig-iron. Four of these furnaces, of 2500 h. p. each, are being erected, and also electric steel furnaces to manufacture steel from pig-iron. There is already a small furnace running in Norway near Tinfos, Nottoden, and the Norwegians are active in organizing other companies to manufacture iron and steel electrically.

I have been speaking of the pig-iron industry. I will refer briefly to the Swedish and Norwegian steel industry. Steel is made principally in Sweden by the bessemer and the open-hearth processes, both acid bessemer and basic bessemer, acid open-hearth and basic open-hearth. They make steel like past-masters. It is a pleasure to see a Swedish steel-maker run a bessemer converter. He takes his time to it. He is not interested in mak-

ing a tonnage record, but he is interested in getting out the right quality, and he takes an immense pride in maintaining the reputation for quality of Swedish steel. They are the most careful and skilful iron metallurgists to be found in Europe. The first commercial electric steel made in the world was made in Sweden. Mr. Kjellin invented the induction furnace, putting up a small furnace in 1903 at Gyssinge, the first one of a capacity of 150

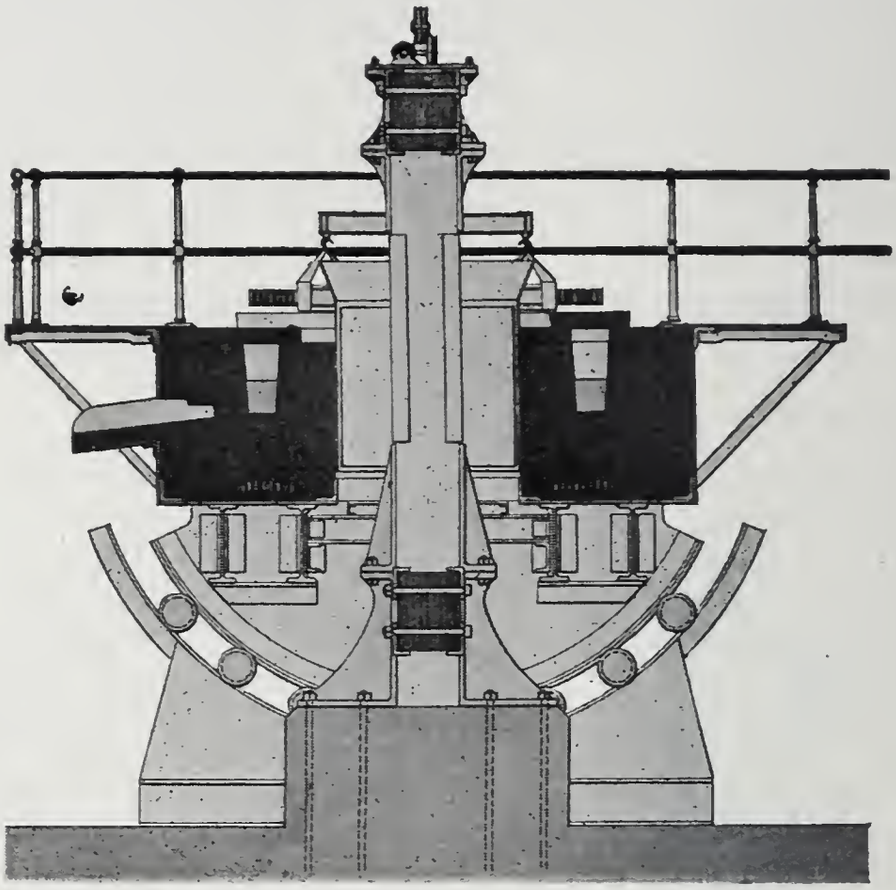

Fig. 9. Vertical Front-Back Section of Hiorth Induction Furnace.

lb., shown in Figs. 3, 4 and 5. In that furnace he used power at the rate of nearly a horse-power-year per ton of steel, but he turned out good steel. He took the materials that are ordinarily melted in the crucible, the best Swedish pig-iron and soft wrought-iron, and melted these in his induction furnace to crucible-quality steel. Then he made a larger furnace, one for a half-ton, then one for a ton and a half, and the amount of power required to make his steel, per ton, went down in a surprising manner. It took 7 000 h. p.-hours for the little 150-lb. furnace, and it went down to 700 per ton in the five ton furnace. This is another striking illustration of the fact that the larger you make

a furnace and the harder you work it, the more economical and efficient it is, particularly on the thermal side. Mr. Kjellin developed his induction furnace and made a market for his electric-furnace steel. It was introduced into the different steel workshops of Sweden and was found to be the equal of crucible steel. It was taken up by the Siemens and Halske firm in Berlin and they have worked it on a large scale in Germany. The principal works in Germany is at Volklingen, where there are now induction electric furnaces up to 15 tons capacity. The improvements in the induction furnace by Rochling & Rodenhauser have been so great that they have practically outstripped the simple Kjellin induction furnace, so that it is now no longer used.

The furnace which interested me most and which I saw in operation on the Jossingfjord, in Norway, was the Hiorth furnace, shown in Figs. 6 to 12 inclusive. There is a description of it in the last volume of the Transactions of the American Electrochemical Society, Volume XIX. Mr. Hiorth is a young Christiania man, a graduate of the Royal Polytechnicum. His father is a well-known hydraulic and civil engineer, and the young man has devised several electric furnaces. I went down to the place where he has a five-ton furnace running and saw it in operation. That was the place where the power cost $4 per h. p. year. What they were doing was this: Taking the soft Swedish wrought-iron and Swedish pig-iron, intercepting them on the way from Sweden to Sheffield, melting them together in the electric furnace and shipping the ingots to Sheffield. This was merely replacing the melting in the crucible in Sheffield by melting in the electric furnace in Norway. The cost of melting in Norway was less than $5 a ton, whereas in the crucible in Sheffield it was over $20 a ton. They did not attempt or need to refine it; the materials simply needed melting together.

There is, however, another possibility, and the Norwegians see it. Norway has always had a sea-going people and there is around the coast a great amount of marine scrap-iron and steel which at the present time has to be sent out of the country and is shipped to England or Germany to find a market. The Norwegians are saying, "What is the use of our sending to Sweden

and buying high-priced material? Why not take this old scrap material, refine it in a properly constructed electric furnace, and make from it a high-quality steel?" This is the line along which the Norwegians will push hard in the next year or two. A number of electric furnaces are being constructed along the coast to work up the large quantities of scrap-iron and steel available, into a steel of a higher quality than could be made in an open hearth or bessemer furnace. They will thus create a new industry, utilizing their scrap instead of sending it out of the country.

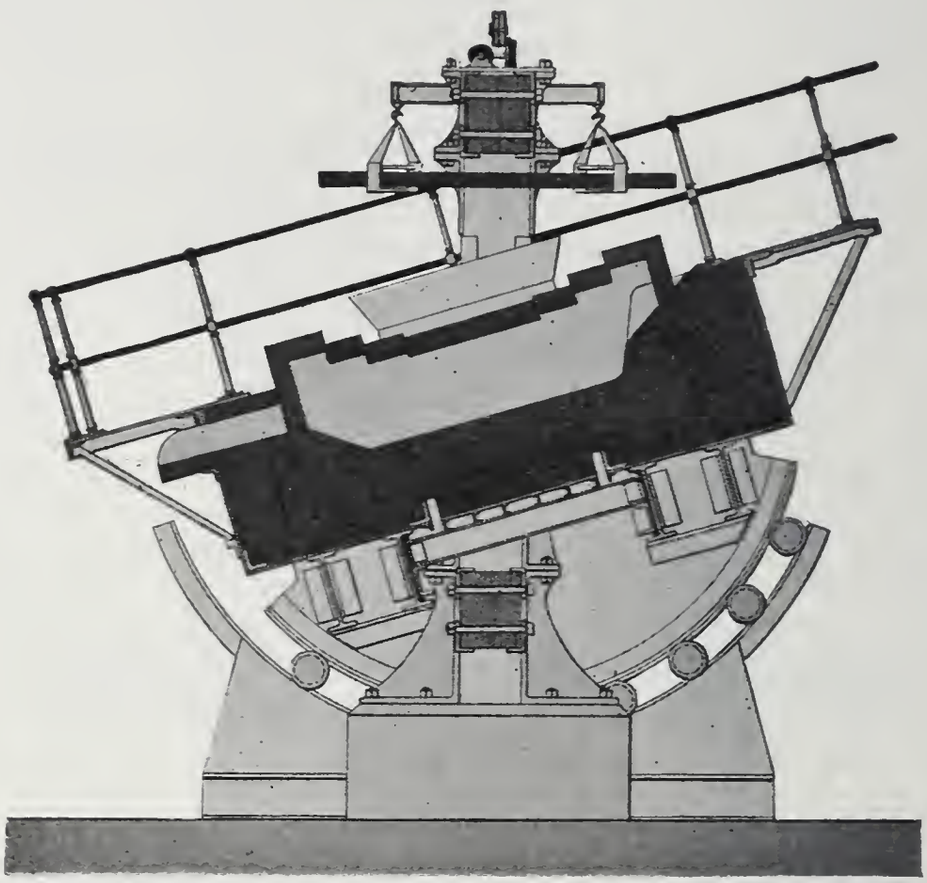

Fig. 10. Vertical Front-Back Section of Hiorth Induction Furnace, showing Furnace Tilted for Pouring.

At the present time the situation in Sweden and Norway is about this: The process of making Norway and Swedish charcoal pig-iron is rapidly being replaced by the electric reduction furnace. It may be five or ten years before the pig-iron industries of these countries will be altogether on the electrical basis, but the change is coming certainly and quickly. The manufacture of steel from the pig-iron, however, will not so quickly become electrical. The bessemer process is so cheap that with

simple water power to drive the blowing engines I do not know anything that could compete with it for making bessemer quality of steel. What I have been advising some of my friends in Sweden to do is to put an electric furnace along side of their bessemer converter and, after they have blown the metal in the converter and have the steel as good as they can make it in that way, then put it into the induction electric furnace. This has no electrodes, it is simply a reservoir into which they would pour the hot steel from the bessemer converter, turn on the current and let it go. The steel would be simply left there to settle in a non-oxidizing atmosphere, to be quiet so that the impurities can rise out of it like the clearing of muddy water. This would give it a "dead melt" and improve the quality considerably at a very small cost. If you do no refining in the furnace there will be practically no wear on its lining. I have figured out that the maximum cost in Sweden would not be over 20 cents a ton for thus giving their bessemer steel a "dead melt." Anyone who makes crucible steel knows what a "dead melt" does for crucible steel.

I saw a blast furnace at Domnarfvet run in this way. They tapped out a ladle of iron and closed up the tap-hole again, as if it were a cupola, took the ladle of iron to a basic bessemer converter, blew it, and poured it out. That steel was a little bit wild. From such basic bessemer converters they get a heat every 30 minutes. I suggested : "Why not put that charge in an induction furnace, leave it 30 minutes, and then take it out and cast it? I think at a minimum cost you would greatly improve your steel."

I mention this because it has perhaps some lesson for us. I believe right in this Pittsburgh district all our bessemer and open-hearth steel could be considerably improved by simply allowing it to remain for half an hour in an electric furnace, where it would rest itself, allow the suspended oxides in it to settle out into the slag, and give the steel a "dead melt." In fact, a month ago I wrote to Mr. Hiorth of Christiania, and said, "What is badly wanted in America is a furnace that will take the whole charge of a 50-ton open-hearth furnace." I have here a design which Mr. Hiorth has made for a 30-ton induction

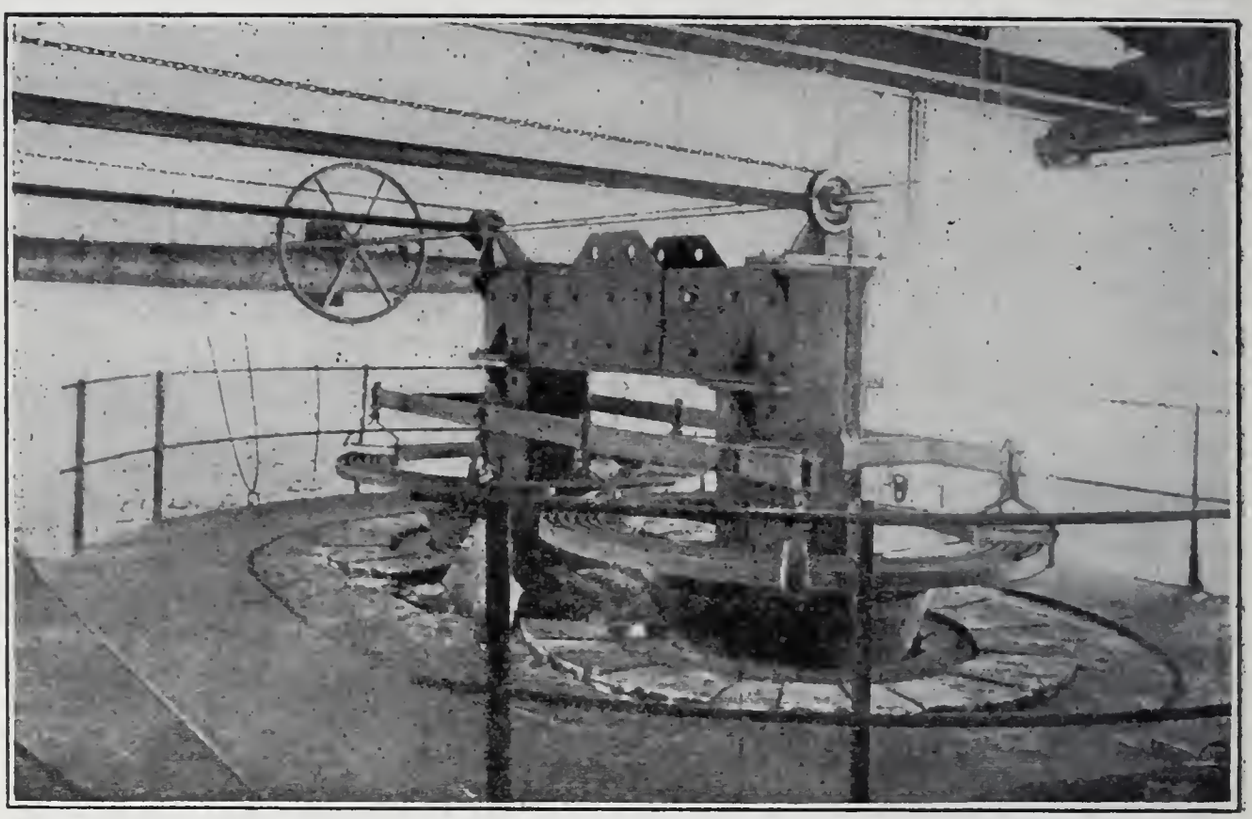

Fig. 11. Top View of Hiorth Induction Furnace.

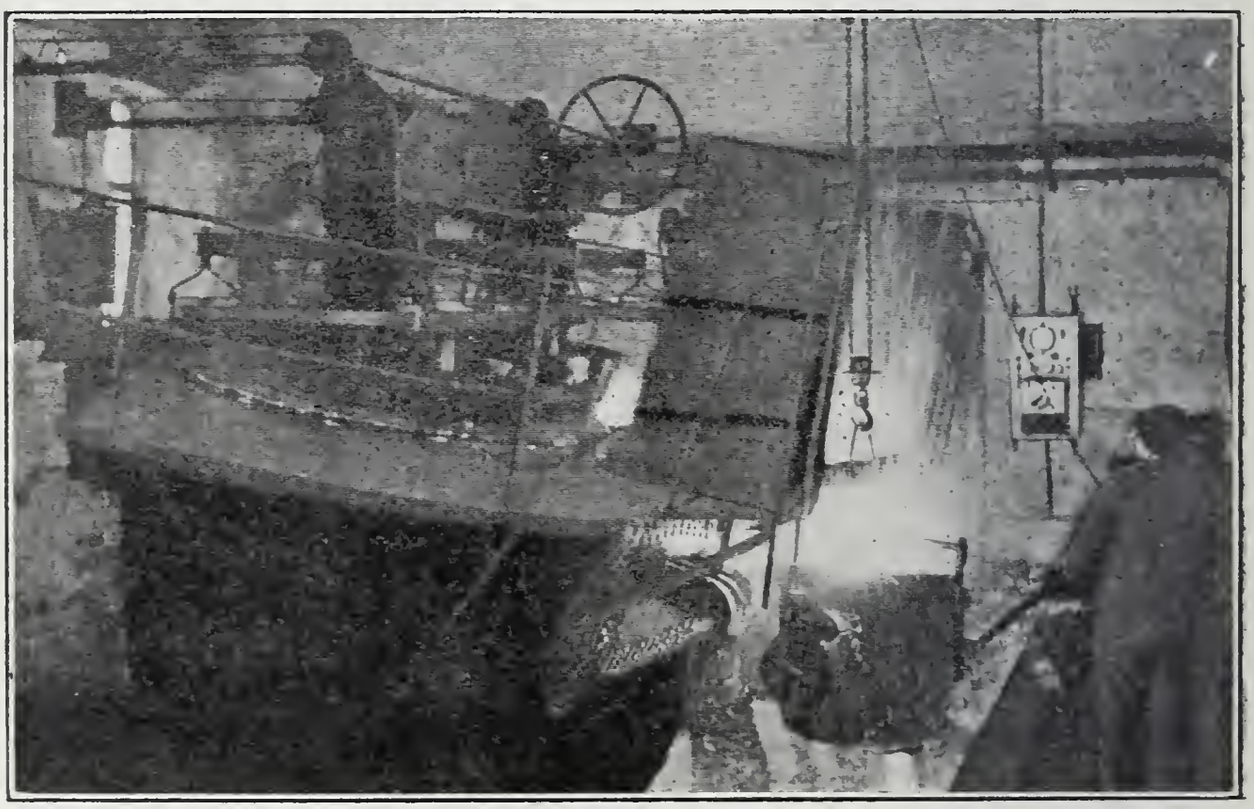

Fig. 12. Hiorth Induction Furnace Pouring a 3-Ton Heat of Crucible Quality Steel.

furnace, which will be presented for discussion to the American Electrochemical Society. It is a three-phase induction furnace. Steel can be kept melted in such a furnace using not over 20 kw. per ton of steel. The largest furnace in the United States to-day, a 15-ton furnace at South Chicago, requires 50 kw. per ton of steel to keep the steel melted. Keeping power a half hour on the 30-ton furnace would absorb only 10 kw. per ton of steel. The cost of keeping steel melted runs down very rapidly as the size of the furnace is increased, and when we have a furnace equal in size to our open-hearth furnaces I believe the cost of giving the steel its finishing electric-furnace treatment will be ridiculously small as compared with our usual ideas on the subject.

I have given a rather sketchy account of what is to be seen in Norway and Sweden, and of the rapid changes taking place in the iron and steel industry there. It is perhaps sketchy because what I saw was largely in process of change and construction. I saw several furnaces being erected and was told: "If you come back next year you will see us running." I answered: "If I possibly can I will", and I now plan to go over next August to see these furnaces working. There will be two or three different types of new steel furnaces in operation. There are several pig-iron furnaces which will be running and I know several of my American friends are already over there studying the situation. I do not think it is exaggeration to say that their ancient iron and steel industry is in process of being revolutionized. The hopeful thing about it to me is that the best men in the country recognize these facts. The Jern Kontoret, capitalists and the industrial people all recognize the situation and see that the only way to save their iron and steel industry is to adopt electric methods. I had a conversation of about half an hour with Crown Prince Adolph, finding him a very bright young man, and soon saw that he understands the situation clearly; it was pleasing to see his grasp of the economic side of the situation. An influential banker of Stockholm held entirely similar views. They both understood that a revolution in their established industries was already taking place, also that their country was benefitting greatly by the inauguration of a number of new

industries (of which I have not said anything; for instance, the nitrate and the calcium carbide industries and others which are being established), and that all this meant a new era of rapid industrial advance for these northern countries.

Now there is a country to the north of us, Canada, which is very similarly situated. I think the Canadians are already sizing up their situation in a similar way. Dr. Haanel, Government Director of Mines, has been sent over several times by the Canadians to seen what the Swedes and Norwegians are doing, and in the near future I think we shall have, nearer home, some very interesting developments along these lines. The Fall meeting of the American Electrochemical Society, in Toronto, September 21-23, will probably bring out a large amount of interesting information about these and similar electrochemical developments.

DISCUSSION

President Walther Riddle: I think this is one of the most interesting papers we have ever had, not only for its scientific interest but because it has that touch of personality that makes the whole thing so close to us. There may be questions which you would like to ask Dr. Richards. I would like to ask if there is much tide in these fiords.

The Author: Not much. To my remembrance about five or six feet.

Mr. Walther Riddle: Not enough to use tide-mills?

The Author: No.

Mr. W. A. Bole: I have heard a good deal about the wonderful irons of Sweden, but I have had no personal experience with them, and I would like to know in what regard Swedish iron differs from our everyday American iron produced in this region. Is there a way of stating it briefly?

The Author: I cannot state it briefly, but the particular characteristic of Swedish pig-iron is that it is very low in sulphur and phosphorus, and the wrought iron made from it is extremely pure and good for steel-making. Then there is another quality which can hardly be expressed in words. The

analysis does not explain the difference. And there are characteristics to the electrical-furnace iron. While you can hardly get a steel-maker to put it in words, yet he will tell you that there is a difference when he turns it into steel. He would probably say the steel had more "body", by which he means something which every steel man thinks he understands, and no outsider does.

As for foundry iron, I do not think they are using it for foundry purposes. They are using it mostly for steel. It is too good to put into the foundry. They can sell it for a higher price than the best charcoal blast-furnace iron. What you ask brings up a very interesting point. They are making some iron in the electric pig-iron furnace that has only 1.5 per cent. of carbon in it, and they do not know what to call it. I told them that was easy: "Call it *pig-steel.*" Its carbon corresponds to steel and it is in reality crude, impure steel. They have not quite got the hang of making this low carbon material regularly, but when they can do so they have only to run it into an electric steel furnace and refine it, without the trouble of taking much carbon out, and they have steel at once.

Mr. W. A. Bole: In what form is that carbon?

The Author: It is dissolved in the iron. When they make that in the electric pig-iron furnace they are making crude steel straight from the ore and by putting it in an electric refining furnace, taking out the silicon, manganese, phosphorus and sulphur and leaving the carbon, at a low temperature, they have steel at once. That is a possibility which they have their eyes on and which may work out very profitably.

Mr. W. A. Bole: Is none of the carbon graphitic?

The Author: When iron is melted, all its carbon is dissolved carbon, in the combined state. When it cools, some may freeze out as graphite and the carbon stays as combined or sometimes as partly graphitic when it sets. With that percentage it would set all combined carbon.

A Member: What is the voltage of the current in the pig-iron furnace?

THE AUTHOR: About 50 volts, though they have their transformers arranged to regulate it from 40 to 80. But the average is 50 to 60. The current is something like 7 000 amperes. They have even proposed to put the transformers on a platform right over the crucible of the furnace, immediately above the electrodes, so as to have very short connections to the electrode.

MR. WALTHER RIDDLE: Do they have to vary the current very much from the start?

THE AUTHOR: I have not seen the pig-iron furnace in operation, but I understand they put in the charge, turn on the current, and in three or four hours they are making pig-iron; there is very little ceremony about it. I do not think there is very much variation in the current. They start with a higher voltage and work down.

MR. WALTHER RIDDLE: Do they have trouble with bridging and from slips?

THE AUTHOR: I really do not know the details of the troubles they have had, but I do not think they have many. Mr. Loeffler told me they had a few difficulties, but they had surmounted them all without much trouble.

MR. WALTHER RIDDLE: Their ore is pretty uniform?

THE AUTHOR: They size the ore and they have the charcoal sized. They have been trying different kinds of charcoal and different kinds of ore.

MR. VOGT: Referring to the electric blast furnace, is any trouble experienced with the CO_2 uniting with the carbon at high temperatures, giving CO in excess in the gases?

THE AUTHOR: The CO_2 in the gases is always in a good ratio. Do not call it the electric *blast* furnace, because there is no blast about it. The Germans call it very properly "*elektrische Hochofen*" and the French "*haut fourneau electrique*", but we cannot do that. I think we ought to call it either the "electric shaft furnace" or the "electric pig-iron furnace"; we must avoid calling it a *blast* furnace, because there is no blast used.

As far as the gas is concerned, an amount of gas equal to

that which is produced is going away from the furnace all the time and it is so low in CO that they could hardly burn it. It has about one part of CO to one part CO_2. They could utilize it possibly for roasting ore or something like that.

Mr. Vogt: Would the high temperature in the shaft tend to reduce the CO_2 and consequently reduce the efficiency of the furnace?

The Author: At the temperature at which iron is reduced by CO, the carbon would not react upon CO_2.

Mr. W. A. Bole: What are the characteristics of the pig-iron made?

The Author: They can make different grades of iron. They make both white iron and gray iron in the furnace, and I understand they are making a grey iron for foundry purposes.

A Member: Are the ore and charcoal charged in layers or mixed promiscuously?

The Author: I haven't seen it in operation, I really do not know.

Mr. W. A. Bole: A gentleman who was in Europe some time ago made the statement that the Europeans were making grey iron castings out of an iron that he said was as low as 0.70 silicon. Any iron as low as 0.70 silicon that I ever saw was mostly white. I wonder if there is any such iron which is still capable of being cast into grey iron.

The Author: It sounds like iron for malleable castings. It would be a white iron.

MECHANICAL AND HYDRAULIC PRESSES

By Frank I. Ellis*

When asked, about two weeks ago, to give this paper the writer had the impression that there would be considerable data available of easy reference, but very much to his surprise found that there was very little information of a reliable nature that would be of interest to the Engineers' Society on a subject of this kind. Referring to an old text book, Deschanel's Natural Philosophy, published in the very early eighties, it was found that the hydraulic press was mentioned there about as early as any other press. To the writer's surprise he found that the hydraulic ante-dates, as far as our records go, any of the mechanical presses in use known to the earlier engineers.

According to Daschanel, Pascal, a geometrician and literateur of the 17th century, mentioned the hydraulic press in one of his works. While he wrote very little on mathematical subjects, he wrote considerable on love idyls and letters of that sort which were very prevalent in those days, so that it is rather surprising that even a record was kept of his suggestion of a hydraulic press.

Stevanus is also said to have recommended this press at an earlier date than Pascal, but apparently there was no special data kept on the subject.

It was some time in 1638 that Pascal spoke of the press, but it was not until Joseph Bramah invented the cup leather and built the press shown in Fig. 1, that any practical use was made of the machine, as heretofore it was impossible to hold the water pressure between the ram and the cylinder. The patent on this cup leather was dated 1796 and the cup leather was made somewhat as shown in Fig. 2. As you will note, it is very much like the one we use today and there is no doubt that for

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*Chief Engineer, United Engineering and Foundry Company, Pittsburgh.

the low pressures used at that time, these leathers would give as good service as our present day ones on higher pressures. Most of you are familiar with this cup leather, but for those who are not, would say that the principle of the leather is that the water, being allowed to pass between the ram and cylinder,

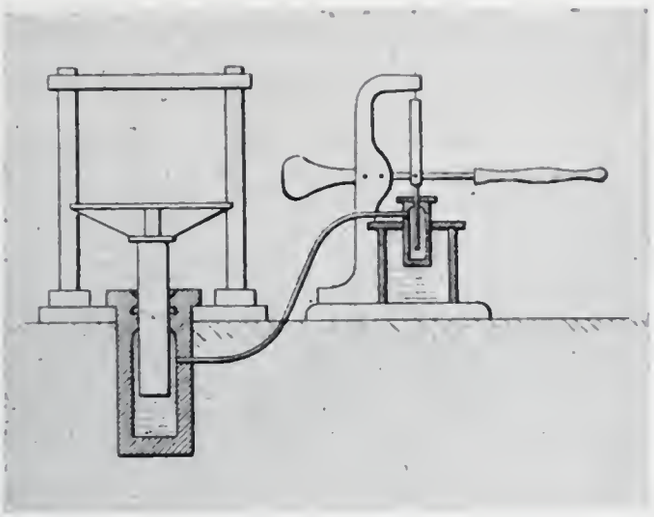

Fig. 1. Bramah's Original Press.

impinges on the lower edge of the leather, which is made somewhat sharp, and the water pressure getting inside the cup, expands the leather forcibly against the ram and inner recess of the cylinder, making the joint. As long as the leather is in good condition, the higher the pressure the better the joint. The friction of this type of leather is considerably less than

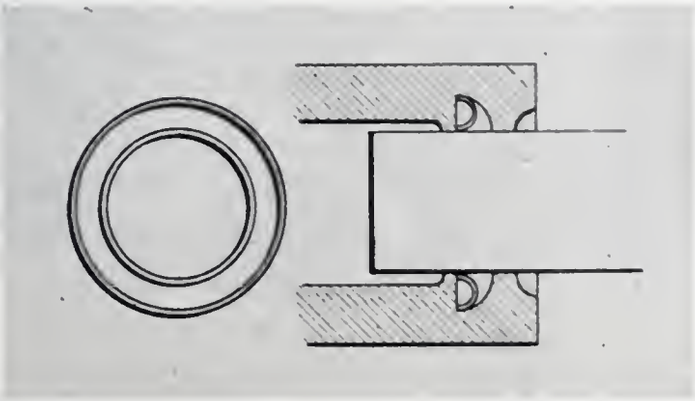

Fig. 2. The Packing in Bramah's Press.

hemp packing for most purposes, but leather is a poor packing where bad water is met with, and in that case it is wiser to use a good tallow hemp packing, care being taken to make the stuffing boxes long, if possible fully one and one-half diameter

of the ram up to medium diameters, and the judgment of the designer must come in on the larger sizes.

One of the earliest uses of hydraulic pressure, which of course was turned into cylinders for other purposes besides pressing, was in the launching of the "Great Eastern." Another was in raising the sections of the Brittania Bridge, these sections being built on top of the cylinders, carried over and lowered into their positions on the bridge by relieving the water in the cylinders. The chocks for launching the "Great Eastern" were relieved in a somewhat similar manner, that is,

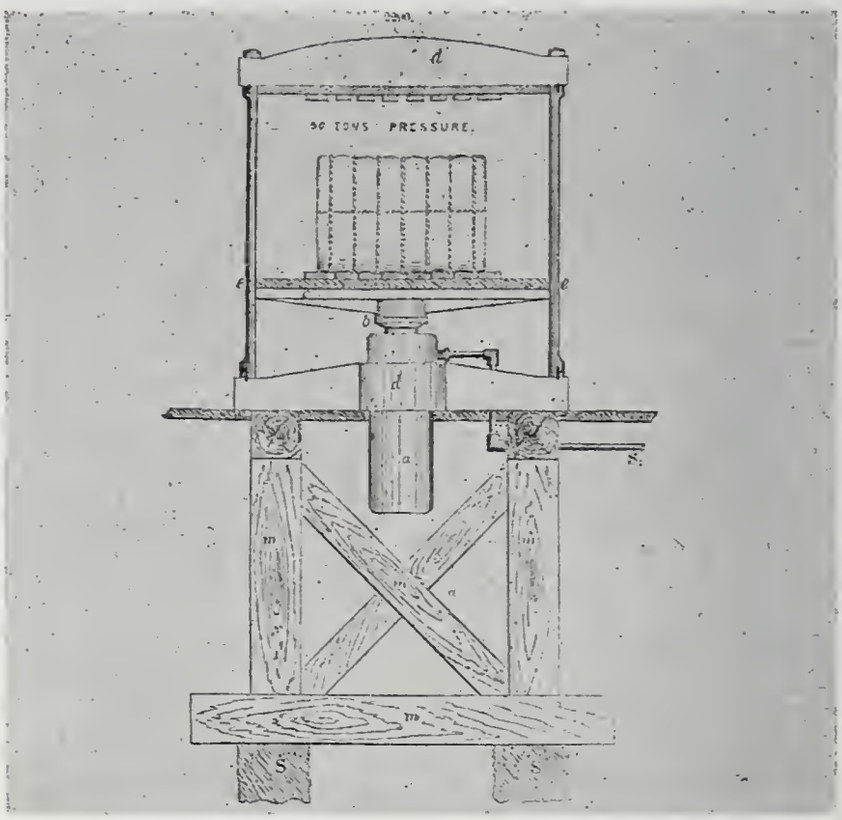

Fig. 3. A Very Old Wool Press.

the load was taken on the hydraulic cylinders, the keys knocked out from under the keel, and at a predetermined time all of the cylinders were relieved, allowing the ship to slide into the water.

In saying that hydraulic presses were the earliest presses used and before mechanical presses, the fact was overlooked that the screw press, which is exactly like the ordinary letter press of today, was invented and used by Caxton as a printing press as far back as 1475, and perhaps even as early as 1456. These earlier presses were made of wood, consisting of two uprights, a head, base and screw, which was operated by a long wooden beam. The writer saw the original Caxton Press, as no

doubt a number of others in the room tonight did, at the World's Fair in Chicago, in 1893. It is regretted that an old picture of this press has been mislaid and the writer is not able to show it to-night. This screw press remained practically unchanged until the year 1800, being used in the mean time for a number of simple purposes, such as making cider, squeezing cotton seed oil, brick work and a number of other purposes, of course mainly for printing, and was superseded as you all know,

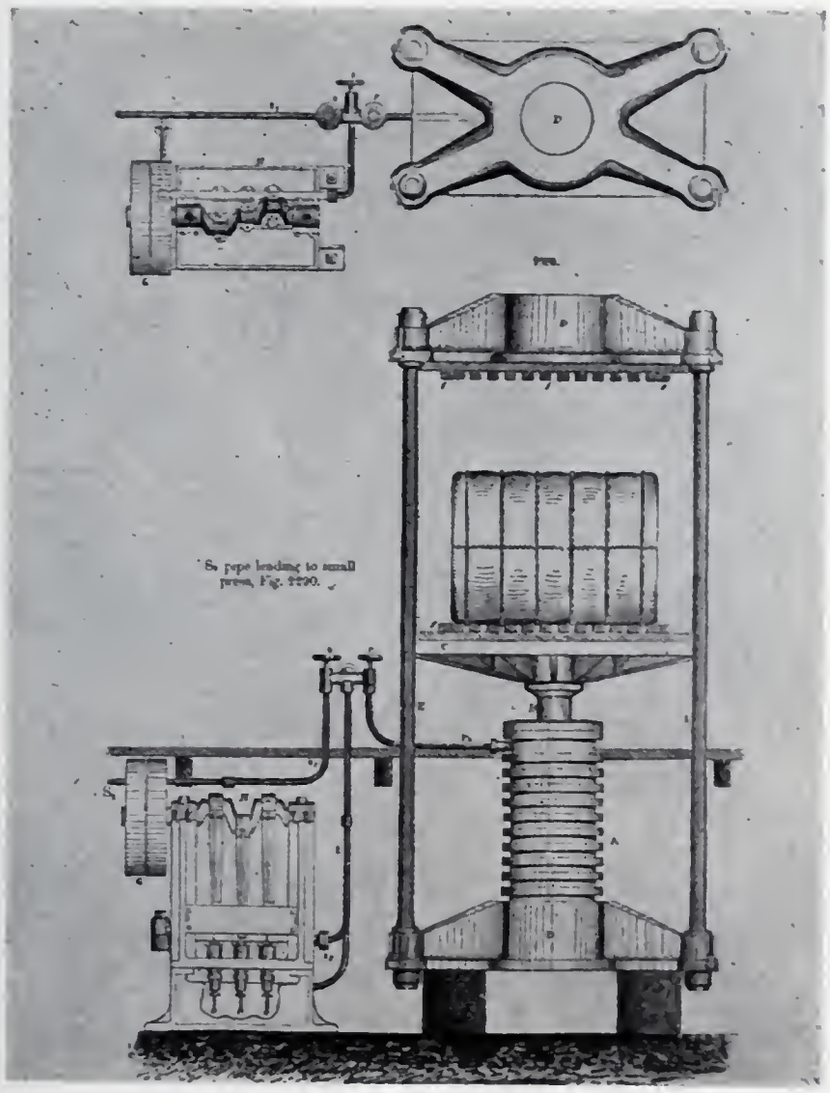

Fig. 4. Another Early Press.

by other styles of presses for this work, which today produce in the neighborhood of 100 copies per minute, handling the paper and ink automatically. However, this is apart from our subject and we will not enter into it any further.

The next development of the press that we find was in the form shown in Fig. 3 which, while very much in the nature of the press in Fig. 1, is only different in general design, the

theoretical condition being the same. This you will note, is a 50 ton press and was presumably driven by a simple engine.

The press shown in Fig. 4 is connected to a triplex pump, driven, by a very simple set of valves, the press in Fig. 3, being operated by the same pump. This press, we believe, was developed about 1796 and is practically the same as many of the presses used in the South to-day. These pictures were taken from some very old prints, many from an old book dated 1840, so that we know this simple operation has not been very much changed.

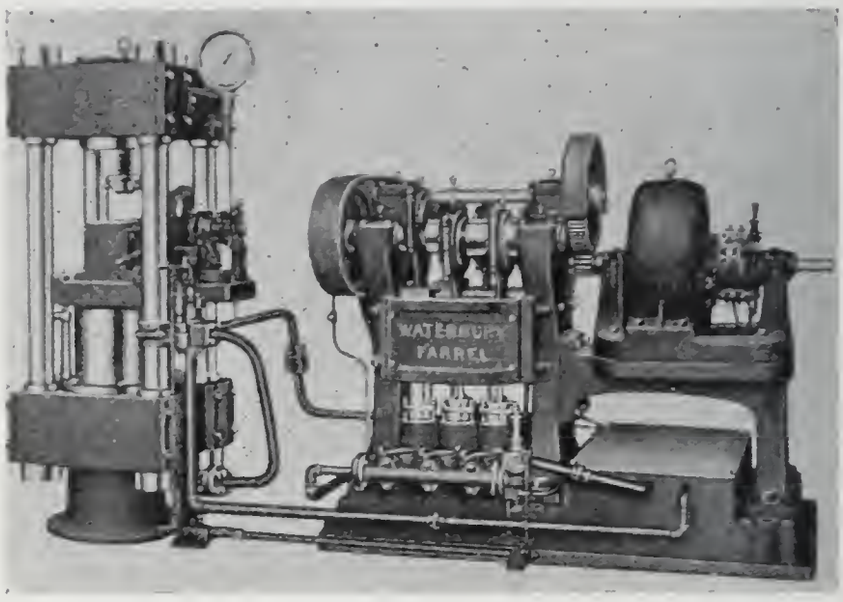

Fig. 5. A Modern Medal Press.

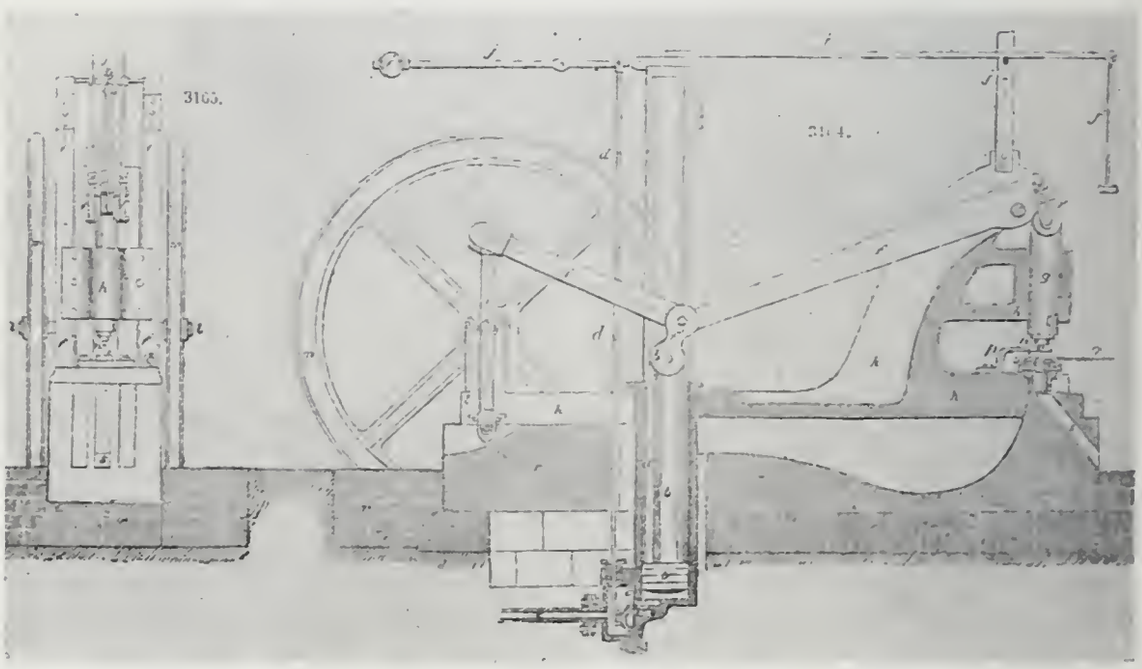

Fig. 6. A Novel French Punch Design.

An up-to-date press builder's machine is shown in Fig. 5, the only mechanical difference being that the original machine had a single hand pump, whereas this latter and modern machine driven by a motor driven triplex pump.

Following this development very closely came a French machine where steam was used to develop the power instead of water, and we have no doubt that the growing use of steam made the French people, who built the machine shown in Fig. 6,

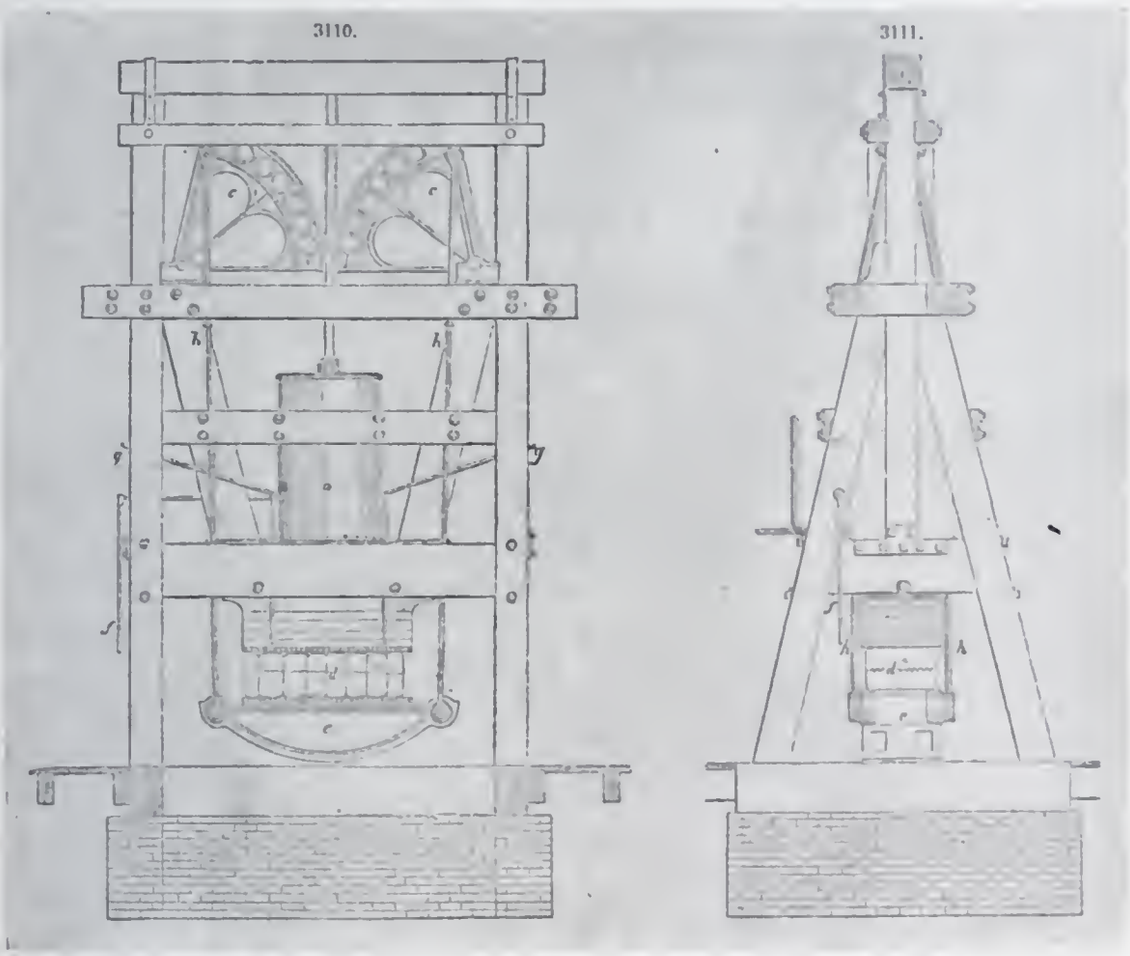

Fig. 7. A Steam Cotton Press with Rack and Cam.

attempt the use of steam for a purpose of this kind. As will be noted, this machine is apparently made for punching and as far as the stripper plate is concerned, it is the same as the modern ones, but the machine has a very peculiar motion. It is one of the most interesting examples of the old machines that we have. Here we see the connection between the power machine and the steam or hydraulic machine, as this combines both, the idea being that the long rod which, although shown as if it were joined in the center, is a rigid beam, one end is hung on the press, giving the fulcrum point of the long lever,

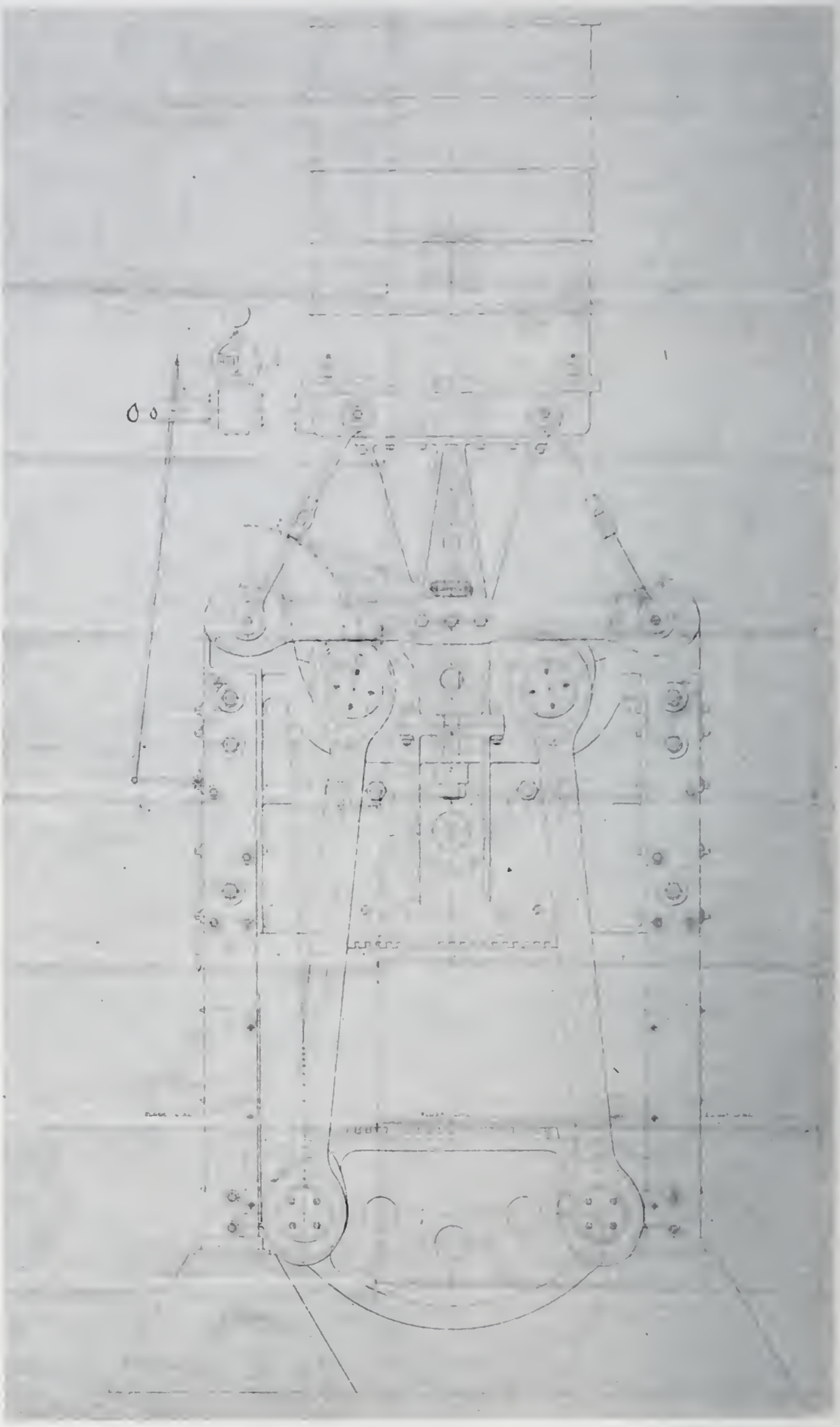

Fig. 8. Webb 2000-ton Cotton Press.

and the other on a crank which has a connecting rod attached to it. The object of the fly wheel kept the writer guessing for some little time and no doubt would others until it was appreciated that the long bell crank lever is not joined above the cylinder, and the object of the fly wheel is to return the steam piston to the bottom end of the stroke. This is a very ingenious machine and, we believe, dates back fully 70 years.

In Fig. 7 is shown another style of steam press which was used for baling in the early part of the 19th century, and is much on the lines of one of the very modern presses of today. This press is for cotton baling and the bottom platen lifts upward, one of the earliest examples the writer has found of this kind of machine. The bottom platen is connected with long rods to two segmental gears which are connected with a rack to the piston of the steam cylinder. When steam is applied to the bottom of the piston the rack moves the segments over and the toggle action is performed, giving a minimum squeeze at the start of the stroke, and the final one very heavy, which is the object to be attained in cotton press work.

In Fig. 8 is shown the well-known Webb press, which is a very typical press in the South today and, is very much like the press shown in Fig. 7, differing only in a few mechanical details, with the exception that instead of a rack they use the connecting rod direct onto the main pin, doing away with the rack entirely. We here see the absolute connection of the steam and mechanical press.

As a slight digression from the regular line of this description, another divergence from the straight hydraulic machines which up to this time have been mostly in vogue is shown in Fig. 9. This is what is known as a steam hydraulic press, also well known in the South and we believe has a number of advantages over the steam toggle press. This press operates with a steam intensifier, putting the water directly into three main cylinders and through the large rods or connections between the upper crosshead and the power platen, carrying the pressure to the bale. This press has an advantage over the mechanical press, having a positive density and a little more surety of the final density attained. It has also some econo-

mies that are not in the other type of press, but for financial reasons (not exactly the price of the machine, but the fact that in the South it is a question of financing, as well as engineering, to get these machines installed) this machine has not been

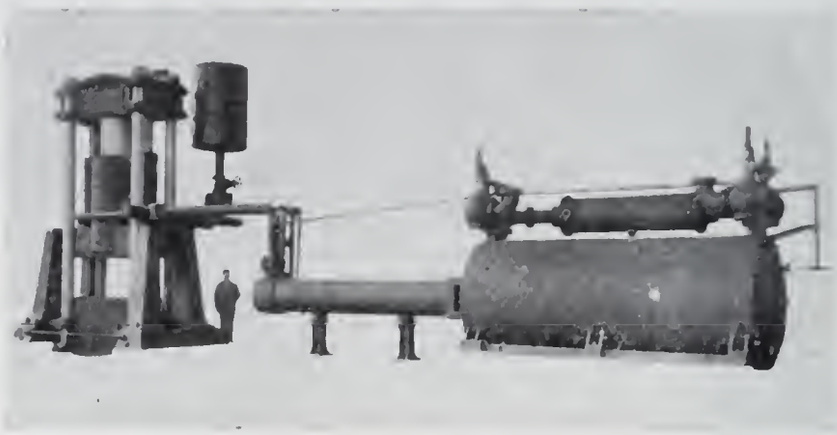

Fig. 9. A Bierce Hydraulic Cotton Press with Pre-Filler Tank.

built as extensively as was anticipated. There is one peculiarity of this machine which will be referred to later which is that the tank shown in the center is used for what is known as a "Pre-filler." The two outer cylinders (of the three on the cross-

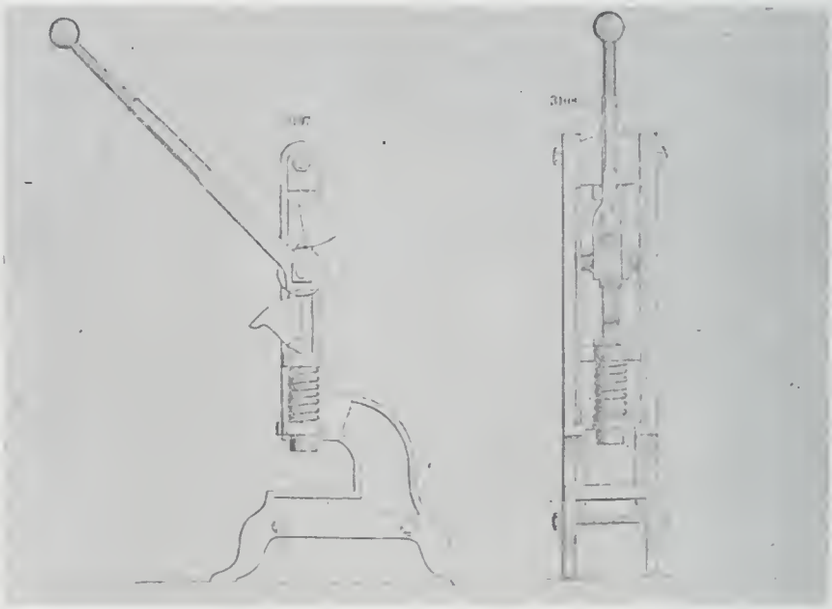

Fig. 10. An Early Lithographic Press.

head) being smaller in diameter than the center one, are used to bring up the first portion of the pressure on the bale, and in the meantime the center cylinder is taking water from the tank, which is usually located about 20, or 30, feet overhead, thus saving high pressure water and getting this cylinder ready to immediately give its final pressure as soon as the intensifier

valve is thrown over to the center cylinder, the press finishing its stroke with the high pressure water in the three cylinders.

About the year 1840, mechanical presses began to come to the front and at the present time are used for manufacturing innumerable articles, among which might be mentioned all lines of sheet metal goods, such as metal boxes, cans, trays, cups, dinner pails, and even such large articles as bread boxes, ash cans, stoves and refrigerators. On moderate size and small work, mechanical presses work very fast, it being very common on hand-fed operations, where strip stock is used, for an operator to catch every one of 120 strokes per minute and on small work such as electric parts, where automatic feeds are employed, it is common to obtain 250 to 350 blanks per minute. Among the earlier presses of this type some are very interesting. For example the one shown in Figs. 10 and 11, which has a so-called frictionless motion. This is to illustrate the early developments, and Fig. 12 shows a machine complete which is apparently a punch, but the writer is not aware whether it worked or not, and is inclined to think if this were used to a great extent there would be considerable wear in the traveling pinion. It is ingenious at any rate, and very interesting. The cut on the side of the slide is an enlarged view of the cam motion of the machine.

A modification of the press in Fig. 11 is shown in Fig. 12, but with a multiplying gear, and we are getting very close to the accepted designs of housings and frames of today.

A combination punch and shear is shown in Fig. 13, and should this be presented as a machine built by some one in the Pittsburgh District today, there would be no criticism of its appearance as this machine (while taken from a very old print) is very modern in its appearance, including the table for serving the material across the front of the punch.

The press shown in Fig. 14 looks very much like a modern machine although taken from the same book, and is undoubtedly a gang punch with the stripping device and attachments of a modern kind. They were all brought out prior to 1850, and contrasted with the press shown in Fig. 15, which was built by one of the up-to-date makers of this class of machinery, it will be

Fig. 11. Details of the Press Shown in Fig. 10.

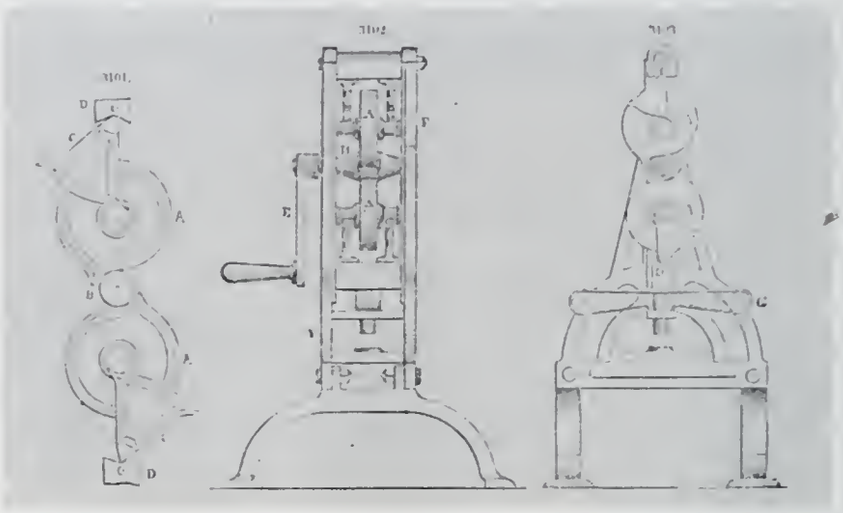

Fig. 12. A Punch of the Same Date as Press in Fig. 10.

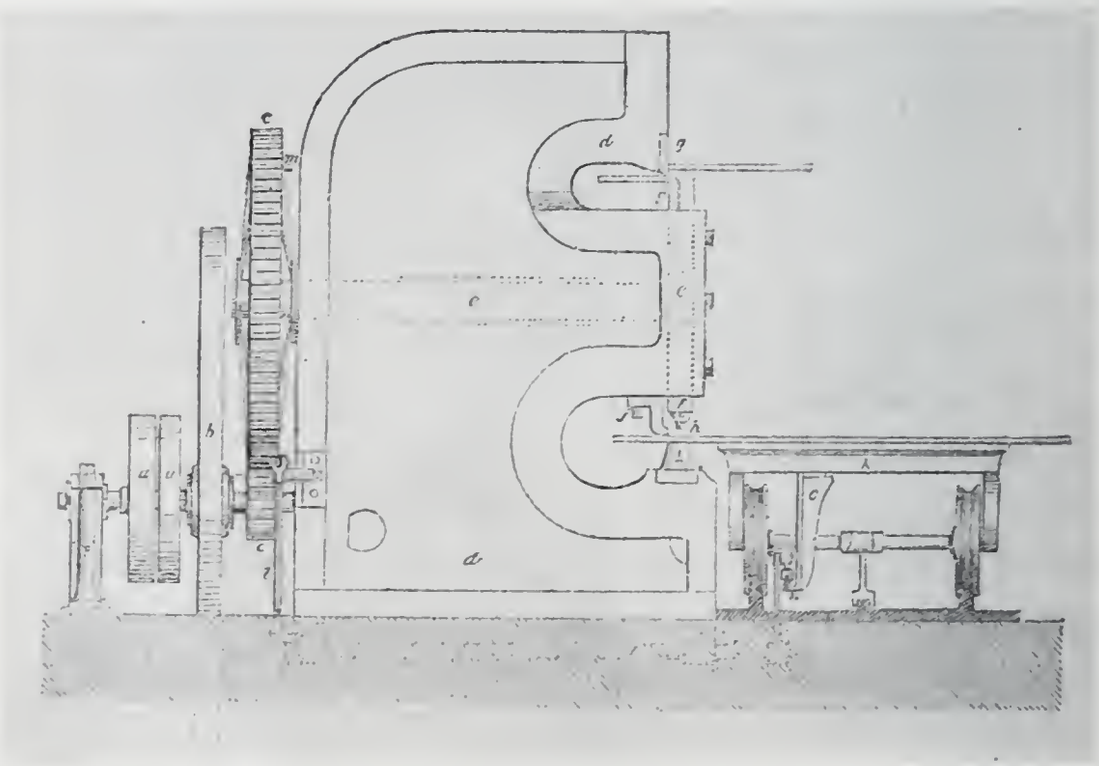

Fig. 13. Punch and Spacing Table.

noted that the progress in this class of work has been in detail only.

The press in Fig. 16 shows a very marked improvement in this type of machine. This is a toggle drawing press which was invented about 20 years ago, and which is perhaps one of the best machines of its kind built today. This press will draw a cup

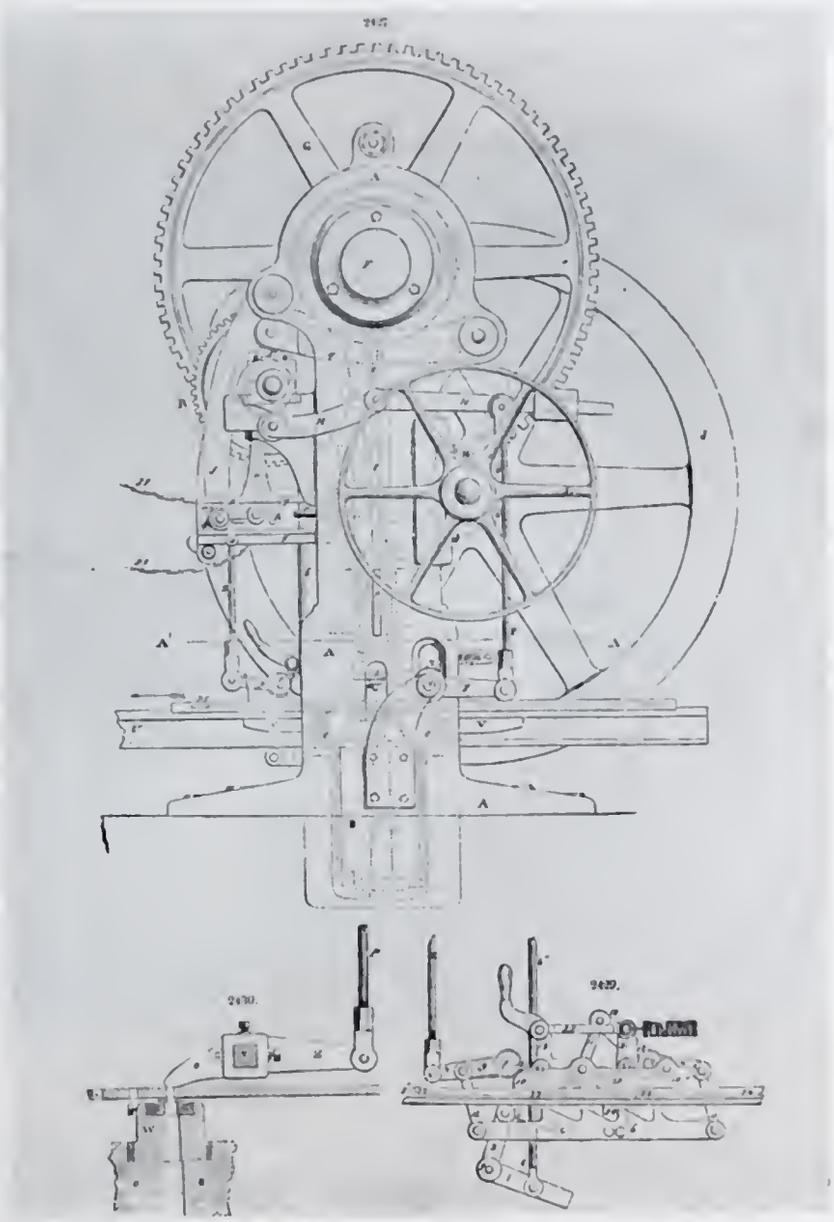

Fig. 14. An Old Punching Machine with a Very Modern Appearance.

from a flat sheet, the improvement being the blank holder or clamping device which holds the sheet flat and free from wrinkles while being drawn.

It was very nearly 300 years after Pascal mentioned the hydraulic press and 200 years after Bramah invented it and made it a practical machine, that presses began to be used to any extent and with any actual practical value. The building of

large men-of-war and large machinery called for very heavy forgings, and steam hammers were gradually made larger until the Fritz Hammer was made at Krupp's works in Germany. In the meantime the hydraulic presses had been developed until presses as large as 2000 to 3000 tons were being made, and one writer referred to a 2000 ton press about 1840 and it was not until about 1856 or 1857 that Sir Henry Bessemer, having considerable difficulty in getting ingots reliably worked through

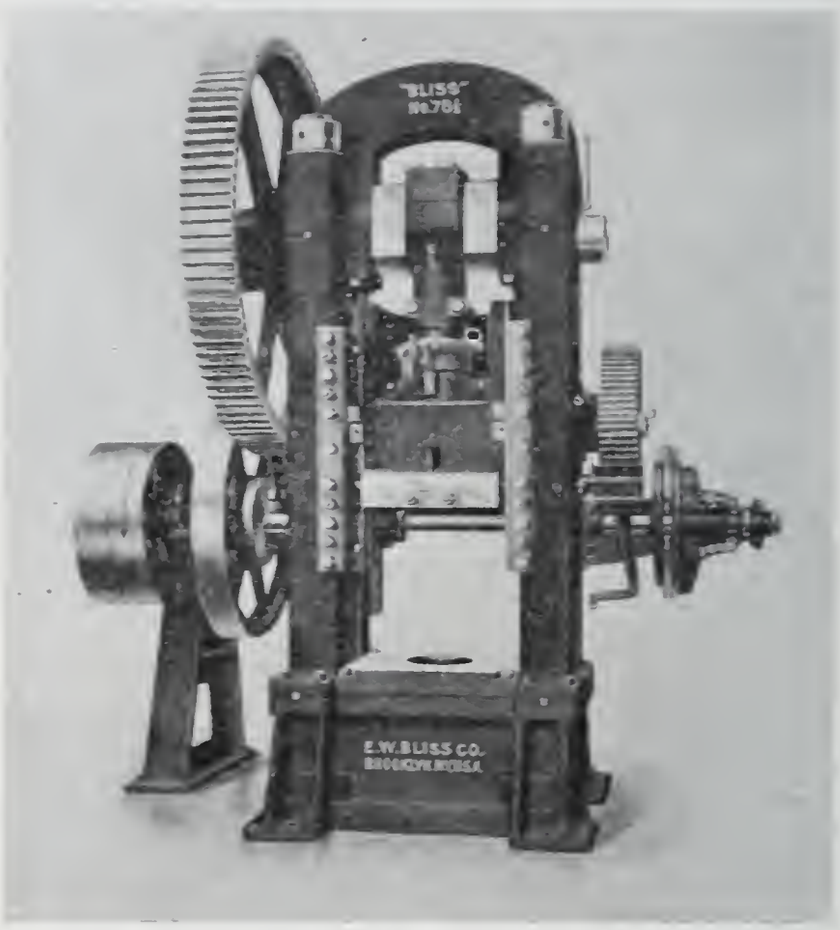

Fig. 15. Double Geared Power Press.

to the center on hammers, took out a patent on a press to do this work, and also some later patents about 1863. One of these presses is shown in Fig. 17, and is a very simple machine, being a combination of a screw adjusting top head and a hydraulic cylinder for the upward pressure to give the final pressure. This was really the origin of the fluid compression of steel, as the same type of press was tried out at Sir Joseph Whitworth's works for this purpose, although this work was actually done before the second patent of Bessemer's was taken out. While this was going on, several other makers were work-

ing towards making the hydraulic press a faster machine, both in Germany and England.

The Bochum press, built in the Bochum Works in Germany, shown in Fig. 18, was quite an advance in this direction. It has a steam cylinder on top of the hydraulic, giving rapid action, and two pull-back cylinders on the side for the return. These, however, are all pump driven presses and the largest examples built about this time of this kind, were as shown in Fig. 19,

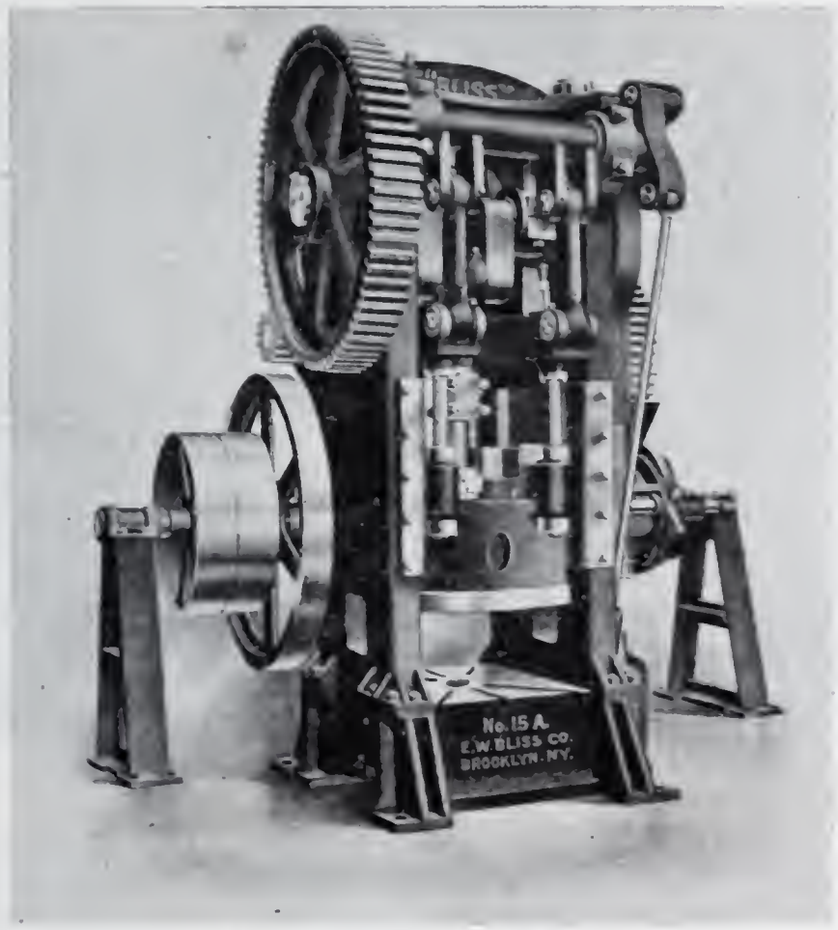

Fig. 16. Toggle Drawing Press.

which illustrates one of the early Davy presses, driven by a pump and is in fact, the same design as the first Homestead press. Several other makers in England, were making presses, all very much of the same kind except that a change was taking place in the pump end of the machine and one of the earliest changes is that shown in Fig. 20 which is an Allen press owned by Sir Charles Allen at Sir Henry Bessemer's works, which the writer saw in operation several years ago. This is a very old machine but still works to good advantage although it is limited (due to its design) to a fixed stroke, but has a varying location of the

upper head. This machine is on the lines of a pump press but is directly connected between the plunger cylinder and the press cylinder, so that there are no high pressure valves through which the water has to pass. It is arranged with a steam cylinder balance and has a pre-filler cylinder operated by a separate lever as shown in the center, the general operation being that the pump is started and if the top head is in the right location, the steam being forced back to the boiler from the

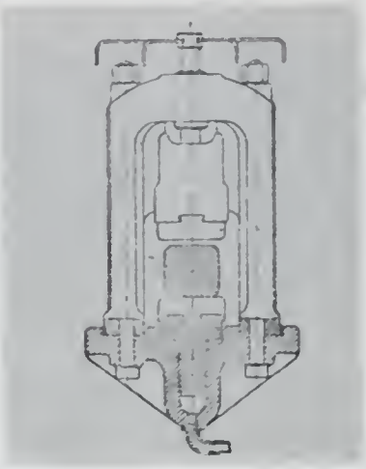

Fig. 17. Bessemer's Hydraulic Forging Press.

balance cylinder, allows the top head to fall on the work. In the mean time, the pre-filler valve being opened, the water fills the gap caused by the head descending and it is ready then to throw in the main engine and pump. This makes it a somewhat slower machine than the modern machines, but a little faster than the regular pump press.

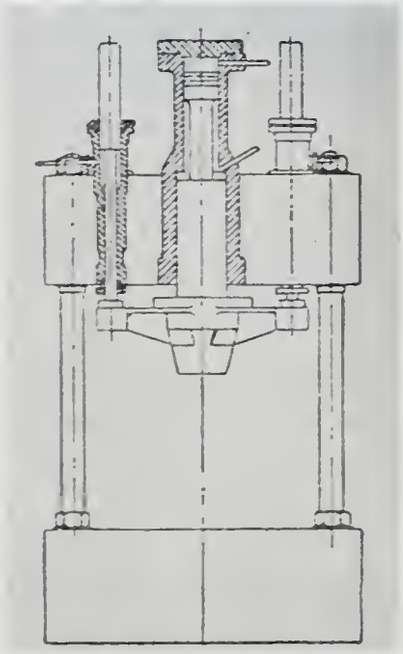

Fig. 18. The Original Bochum Forging Press.

In Fig. 21 is illustrated another well known German press, in which the high pressure water has no valves to pass through and the balancing is done with steam cylinders on top of the machine. This is worked by an intensifier which is shown with the steam cylinder in the lower position and the hydraulic cylinder in the upper. This same press has been lately redesigned and the steam cylinder is placed above the high pressure ram, and the high pressure ram is placed below the floor level. This has the disadvantage that the machine does not re-

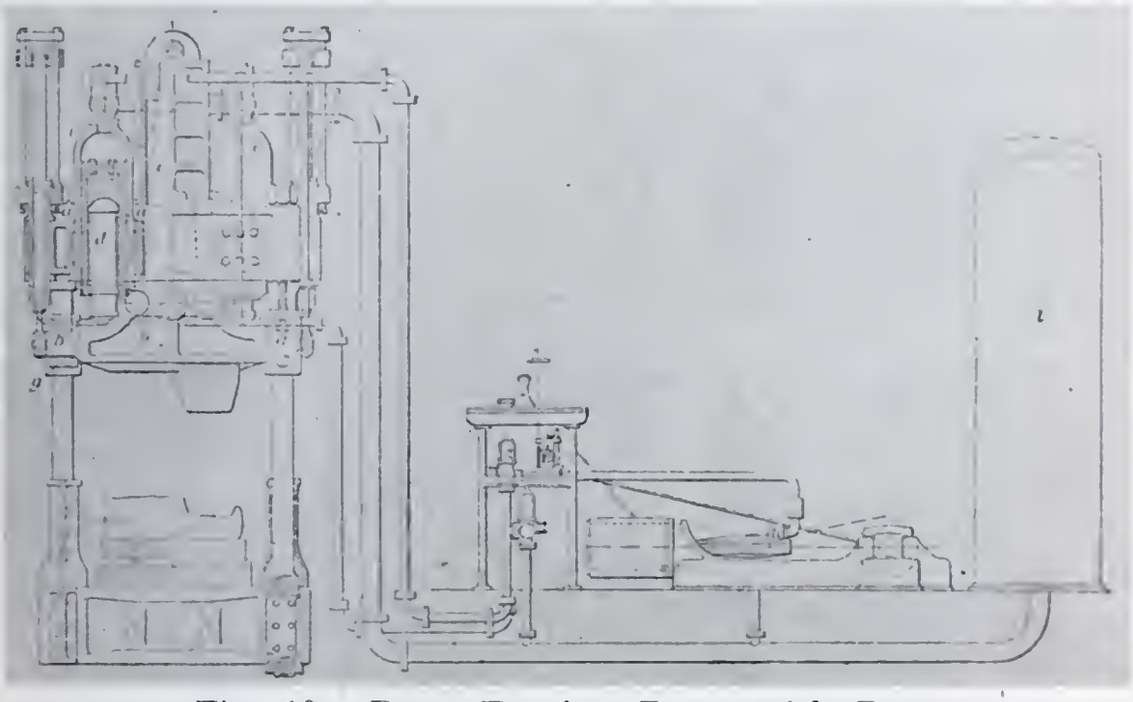

Fig. 19. Davy Forging Press with Pump.

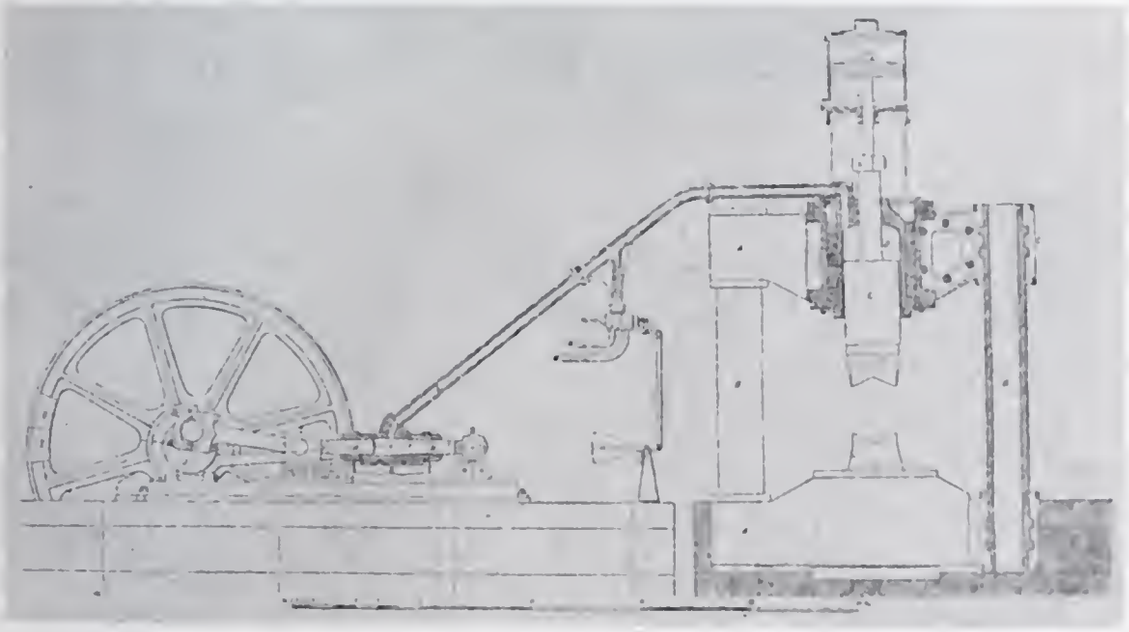

Fig. 20. The Allen Forging Press and Direct Pump.

turn by gravity and has one or two other slight disadvantages also. This particular press was built by an English company.

A later development of the German press is shown in Fig. 22, in which the intensifier is placed directly above the water cylinder, and the piston of the steam cylinder descends into the cold water cylinder, making the ram of the internal intensifier. This is a very nice compact arrangement and in the picture shows up very well. It does away with any long steam

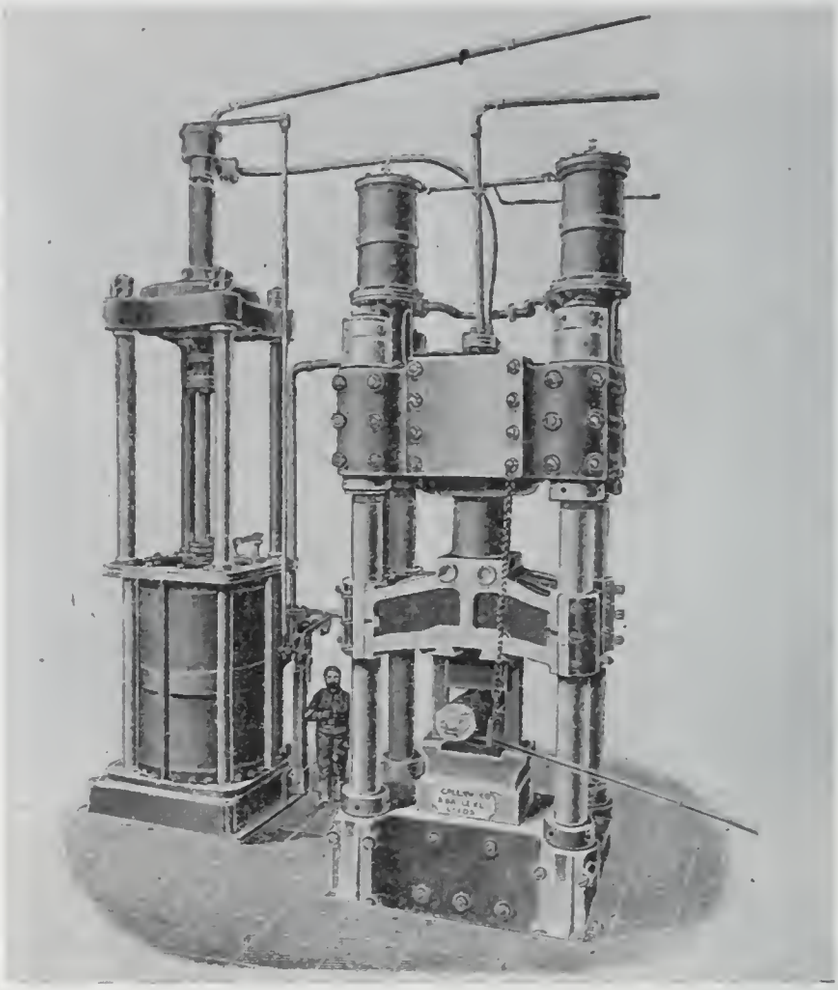

Fig. 21. Breuer & Schumacher Forging Press.

pipes between the intensifier and the main cylinder, but has the disadvantage of putting the hot piston rod directly into the cold water. It is also difficult to get at the stuffing box around the intensifier ram and the pre-filler valve has to be direct connected to the main cylinders. In the press shown, hydraulic power is used for balancing and has to be carried at a pressure of about 250 lb., which also has some slight disadvantages. With this type of press, should the ingot fall from the anvil block, there is nothing to take up the shock of the steam piston descending with accelerated speed, due to the re-

action and also to gravity, and striking the lower head of the steam cylinder. Several devices have been attempted to overcome this difficulty, but as far as the writer knows, they have not been very successful. While the press is about one-third higher than the last one shown, it has the advantage of compactness.

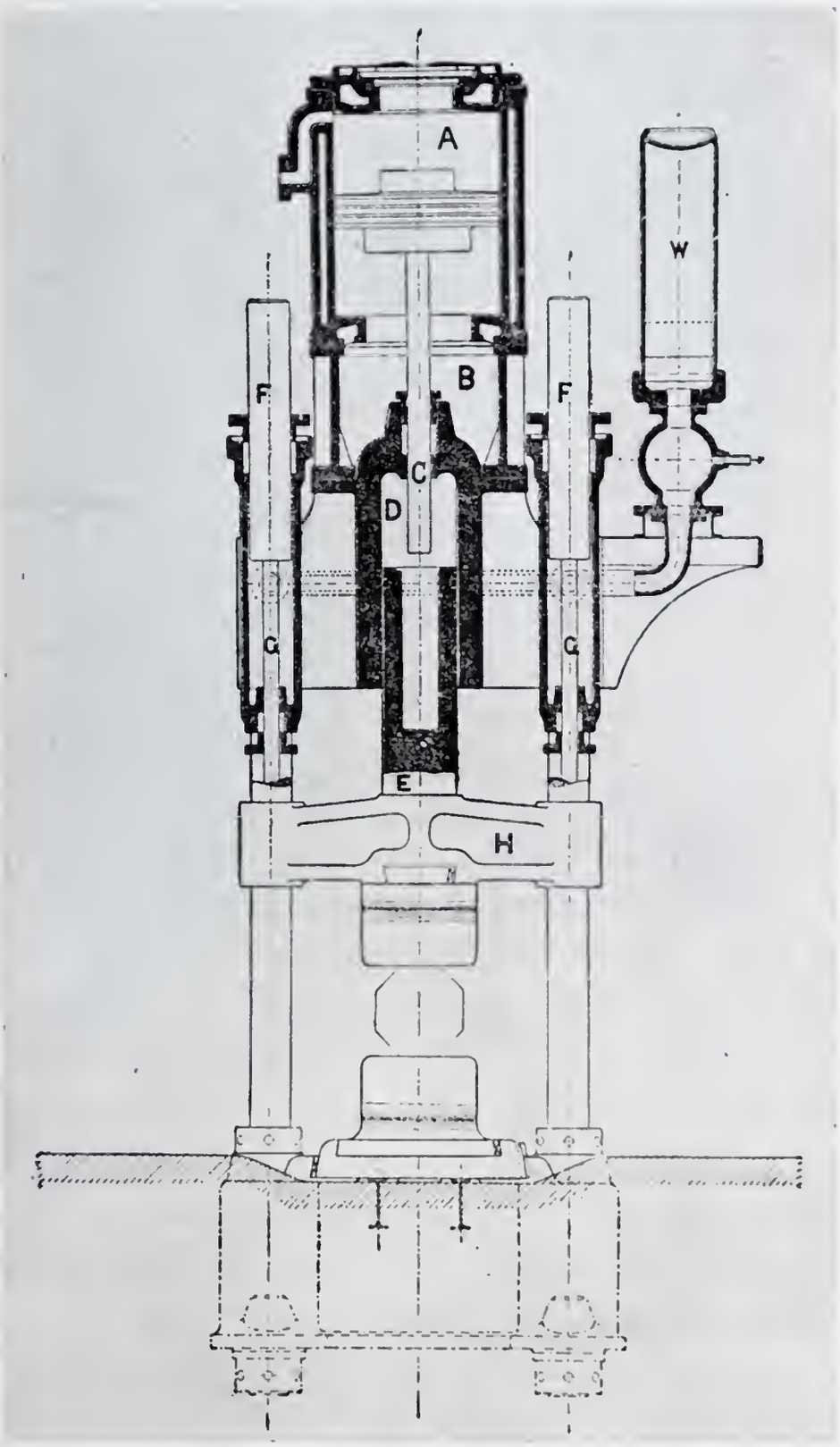

Fig. 22. A German Forging Press with High Intensifier.

All of the steam-hydraulic presses so far described, which make the connecting link between the old plain hydraulic, the French steam and the earlier pump driven presses, are the up to date developments of this class of machinery. All of the foregoing presses are operated by two or three levers, one lever to operate the steam on the main steam intensifier cylinder, another lever to operate the balance cylinders on top of the press,

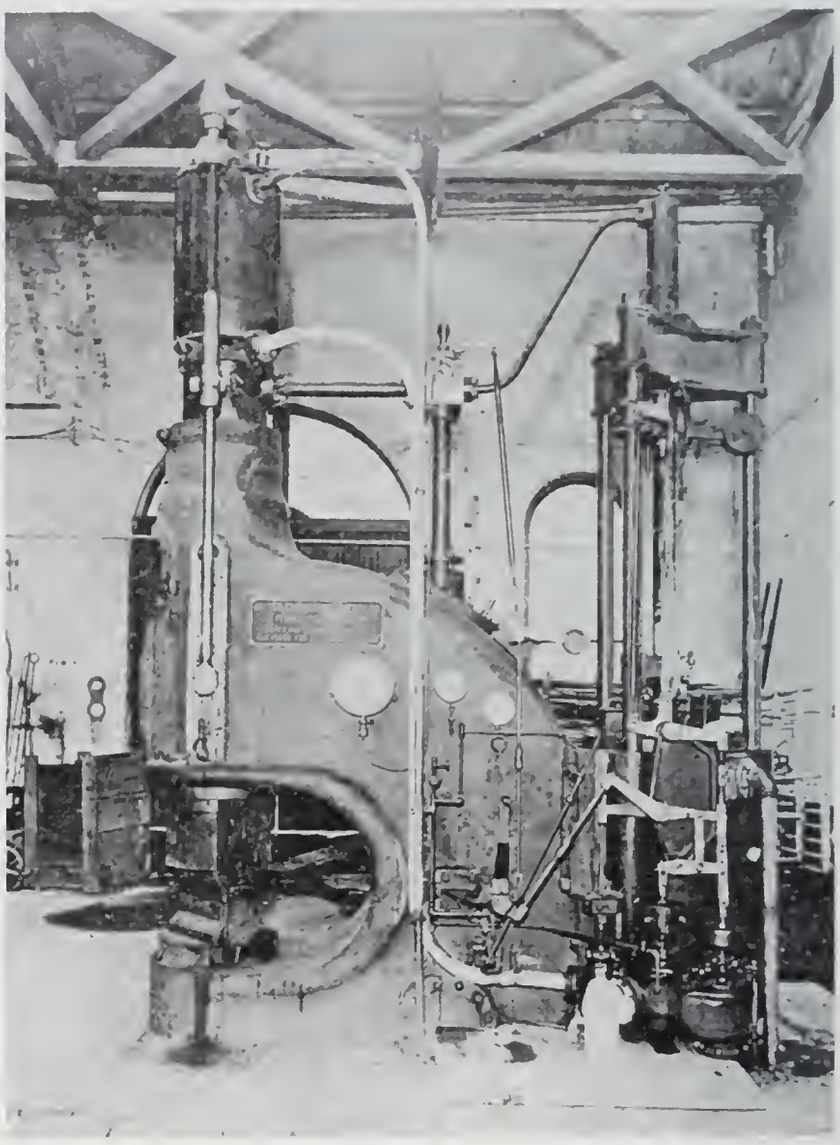

Fig. 23. Davy Single Leg 300-Ton Forging Press.

and in some cases a third one used as a controlling lever for regulating the amount of stroke on the machine. The last two presses use two handles on their small simple machine. The English Davy press, as it was three or four years ago, was very much the same as one of the German presses shown, and was operated the same as they were, by two levers, but Davy Brothers Company at that time developed a new method of oper-

ating these presses and did away with one of the levers, using what is known as a single lever. This press is illustrated in Figs. 23 and 24, showing the small blacksmith type and the heavier machine. A diagram of the working arrangement of this machine is shown in Fig. 25.

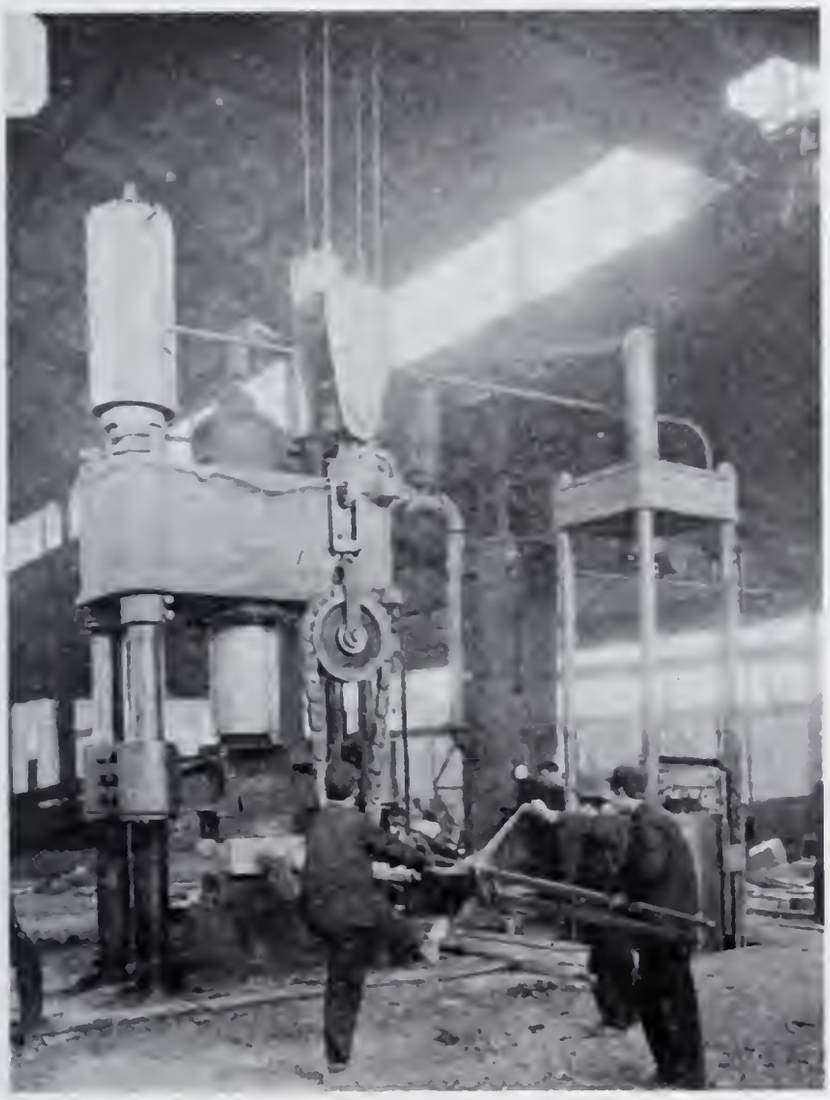

Fig. 24. 1000-Ton Modern Forging Press at Titusville. Pa.

The original Davy press was of the design shown in this diagram, and of the pumping type, the engine being under control of the press operator and also regulated automatically by the pressure, (this is a diagram of a press very much like the present Homestead machine) that is, when the squeeze is in operation the engine throttle valve is opened up to steam and this opening continues as long as the demand for pressure on the ram increases. The pull-backs and main pressure cylinders were both supplied with pressure from the engine.

The diagram, Fig. 26, is of a standard press of today, using

steam cylinders to balance the main crosshead and an intensifier to operate the press. The pre-filler tank is shown in the center and coupled to it is an air chamber to take the shock out of the line. The valve marked "return valve," is placed in the main high pressure line and passes the water from the pre-filler tank into, or out of, the high pressure line, this being done in order to vary the distance between the anvils. The high pressure, however, does not go through this valve but passes around it, the water while under high pressure not being handled, the steam into the intensifier only being controlled and acting directly on the ram.

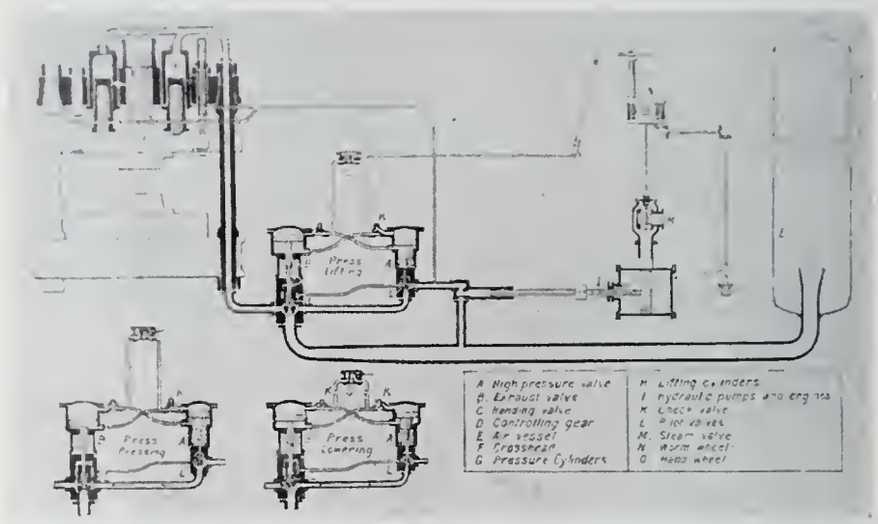

Fig. 25. Diagram of the Original Davy System.

This is a single lever press with a controlling device on the side of the intensifier, this device consisting of an inclined bar carried on two bell cranks and arranged so that an arm on the main intensifier piston will actuate it as the ram goes up. A movement of the handling lever produces a proportionate movement of the intensifier ram, thus:

The handling lever is moved over, opening up the steam valve, the intensifier goes up a proportionate distance, and the ram acting on the inclined bar closes the steam valve and opens

The handling lever is moved over, opening up the steam valve, the intensifier goes up a proportionate distance, and the ram acting on the inclined bar closes the steam valve and opens the exhaust valve. A further movement of the handling lever produces a further movement of the intensifier, the same cutting off as previously. Should the handling lever be moved clear

over so as to give a full stroke of the intensifier, the intensifier will go to the top and automatically close the steam and open the exhaust. It can be seen therefore, that should the work slip from beneath the anvils, or should the resistance be removed from between same, the machine could not be damaged and the intensifier will go to the top and stop without jar to the machine or the operator. Due to this controlling arrangement, the movement of the intensifier, both as to speed and distance,

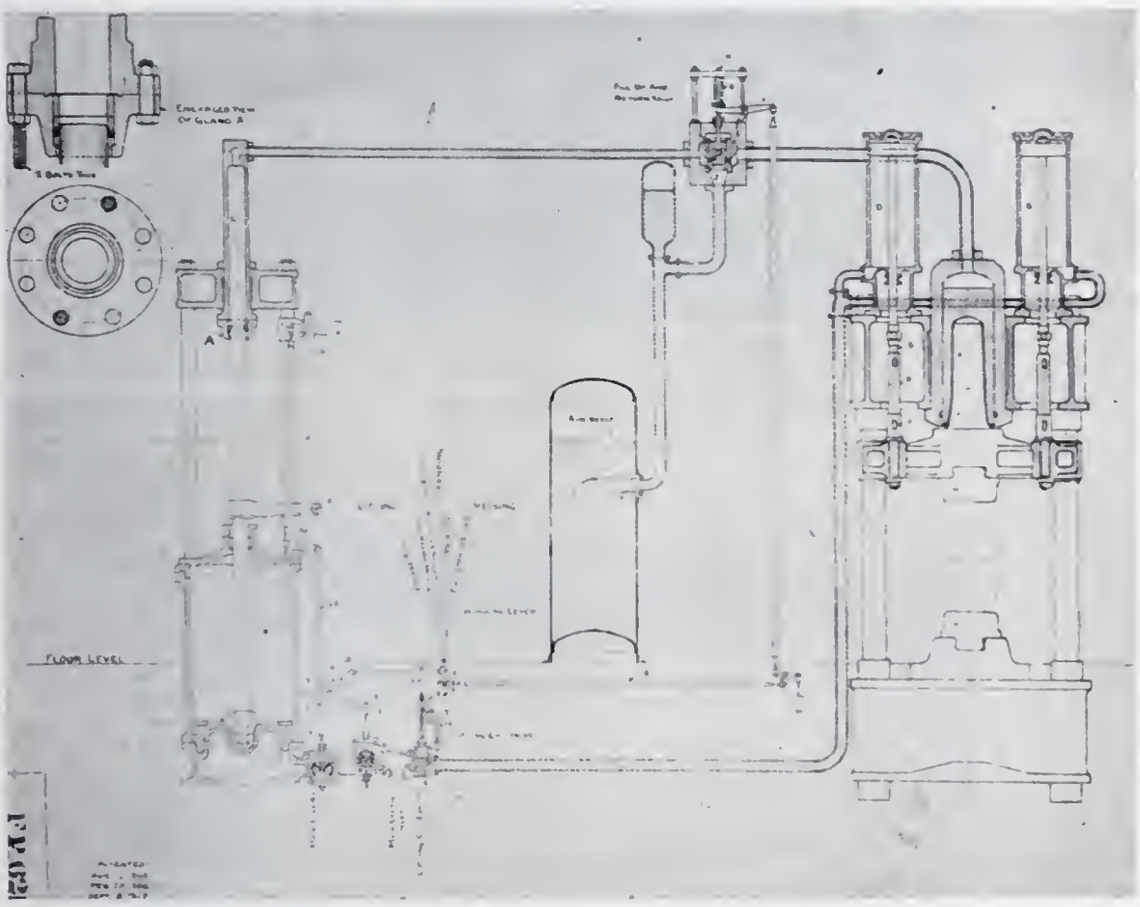

Fig. 26. Diagram of the Press shown in Fig. 24.

is controlled entirely by the movement of the handling lever, so that the operator at will may work the lever fast, thereby working the intensifier fast, or work it as far as he likes, thereby working the intensifier a proportionate distance.

This machine is very economical of steam, using only a proportionate pressure in the intensifier cylinder necessary to balance the resistance between the anvils, and differs from others in one important point, in that it automatically cuts in the balance cylinders so that they are directly connected to the boiler when making forging strokes. They are only exhausted when lowering the head, and when same is done the ram descends and

Fig. 27. Etched Sample of Hammered Ingot.

An etching of a hammer-worked ingot. Note the original shape of the ingot.

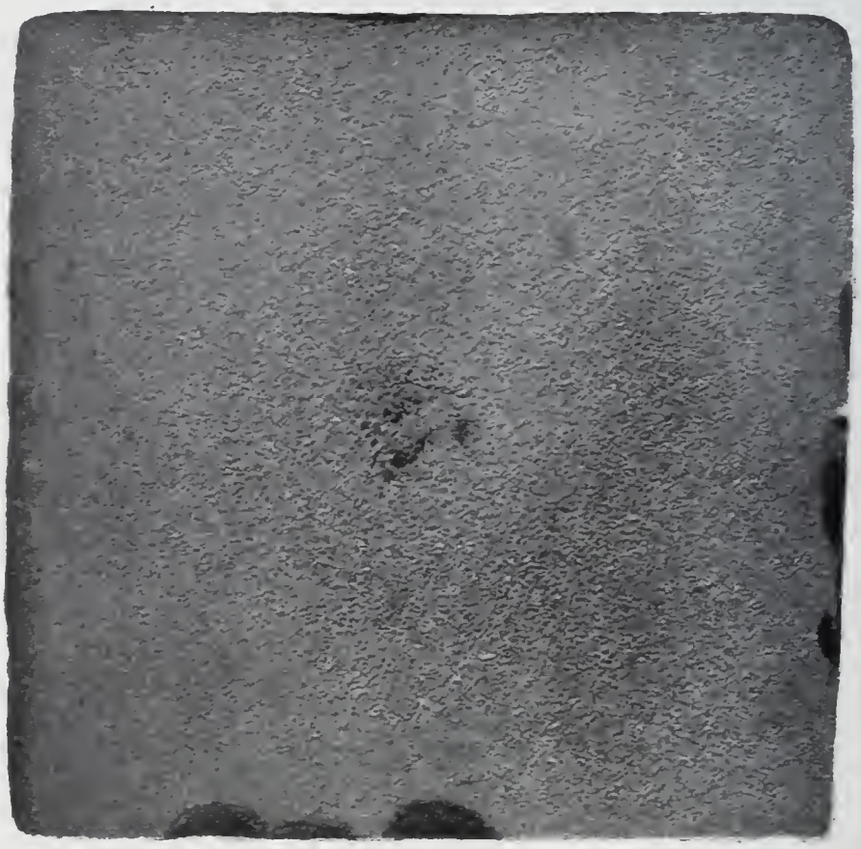

Fig. 28. Etched Sample of Pressed Ingot.

A piece of the same ingot forged under the press. Note the extreme density of the sample, although this was from the top of the ingot.

the water follows up from the pre-filter tank through the return valve.

Another important difference that exists in this machine from others is the peculiar arrangement of the main ram. As you will note, instead of bearing simply on the crosshead, it is on a pintle which is arranged to carry the load directly to the upper side of the ram and press direct onto the face of the cylinder, instead of giving a lever arm to the length of the ram. This is a very ingenious way of getting over a difficulty and works well. All of the operations are performed by a single lever, are very simple and cannot be confused so as to injure the machine.

By following the diagram it will be seen that the forward part of the stroke is used for letting steam into the intensifier and exhausting same. The back part of the stroke is used for opening the return valve to raise press head, the balance cylinder pressure forcing the water back into the pre-filler tank, or for picking up the trip valve to exhaust the balance cylinders and lower the head. This trip valve is an ingenious device for exhausting the lifting cylinders and automatically cutting them in before any pressing is done and, as stated before, the balance piston (when the press is working on forging strokes) pushes the steam out of the cylinders back direct to the boiler and, therefore, does not use any steam; whereas in the hammer it must be used the full length of the piston stroke and a certain amount is also used beneath the piston to stop it.

In watching these machines doing their forging work, the writer has noticed it is very seldom the intensifier travels the full length of its stroke, in fact it need only travel far enough to permit of the turn of the forging between the anvils.

While there is no exact data as to the amount of steam used, from a number of questions asked on the continent, and in England, the writer found that the approximate amount of steam must be about one-half to one-third of the steam used in a steam hammer, doing similar work. While a good deal of theory is given by some makers as to the amount of steam used, we find that in no case is a press used in which it could be stated definitely that the press was using a certain amount. There is

a 1200 ton press operated in this country in connection with a 250 h. p. boiler, which gives ample capacity to operate the press to good advantage.

A feature of the arrangement of this press is that the operating lever is located so that the operator may see directly between the press columns into the press, the operation being a natural motion of the operator; that is, in pressing or coming down to the work the operator moves forward, to lift the press-head to a new location, or to throw the balance cylinders out, the operator moves in a direction away from the press.

The following illustrations, Figs. 29 to 38, indicate the remarkable advance which the press has made over the steam hammer as regards effectiveness and speed of work. The examples of work shown and time of making are authentic, most of them having been done in the presence of the writer and are of interest as showing the commercial possibilities of the press.

DISCUSSION

Mr. G. E. Flanagan: There may be a few gentlemen in the room who, not knowing the speaker well, may possibly have felt discouraged by his opening remarks about the small extent of the information regarding presses he had acquired. It there are such, they have undoubtedly been very agreeably surprised. He has managed to tell us quite a little, and I think if we know enough to ask a few pointed questions he will be able to tell us still more.

I would like to speak a word in a general way of the extent to which presses are used. The thought that was borne in on my mind is the difference between a press that is used in compressing cork in a finely divided condition and other types. Cork is a very elastic material and the pressure required is very small to begin with and keeps on increasing as you get the mass down to a compact body. That requires a press with a long stroke. We most of us every day walk over compressed material made of cork in the linoleum floor coverings. My impression is that this press has about a 1¼ in. stroke with an enormously heavy pressure running up into many tons.

I would like to ask Mr. Ellis in regard to the packing for

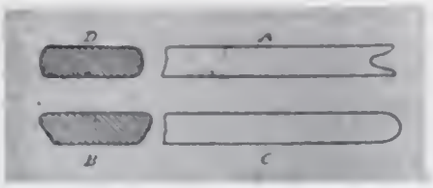

Fig. 29. Comparison of Different Methods of Forging Showing Shape of Hammered, Rolled and Pressed Material.

A B, two views of rolled material showing in A the work similar to a light hammer all on the surface and in D and C the effect of the press, the work extending to the center.

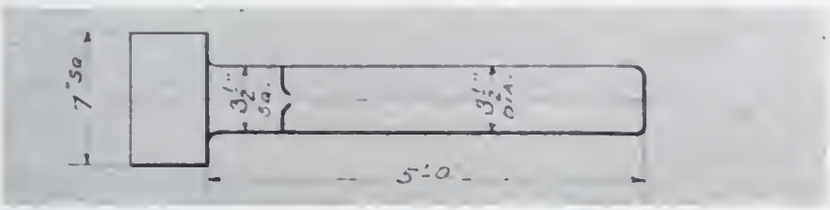

Fig. 30. Made from 7 in. square and cut off in one heat in fifteen minutes, on 150-ton Press.

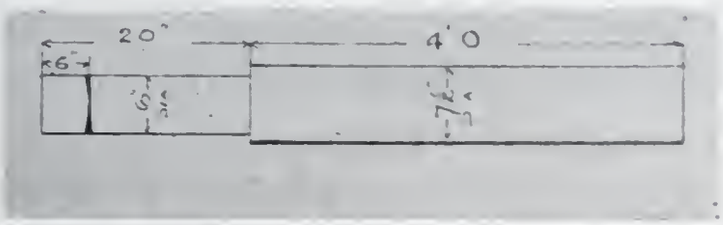

Fig. 31. Round Shaft made from 8 by 8 in. billet. Time, 12 minutes on 150-ton Press.

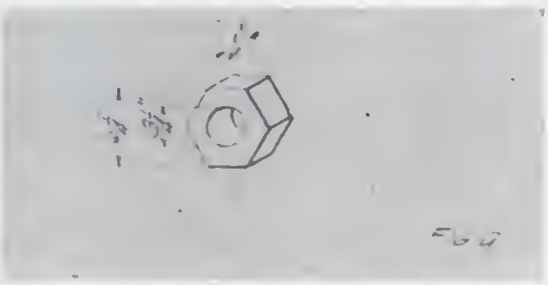

Fig. 32. Hexagon Nut, 6½ in. across flats, upset from 5 in. stock and punched in ten minutes on a 150-ton Press.

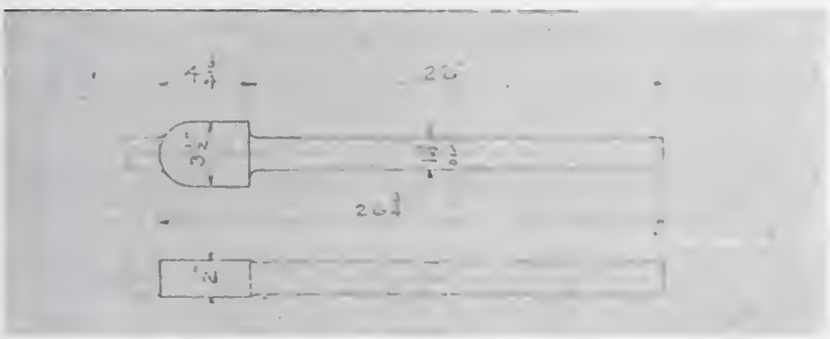

Fig. 33. Piece forged from 4 by 4 by 12 in. stock in one heat in four minutes.

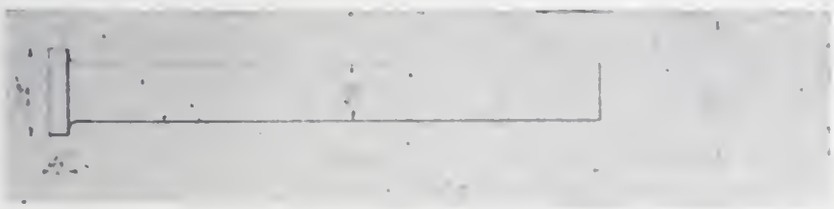

Fig. 34. A 14¼ in. shaft, 20 ft. long, with coupling on one end, from a 36 in. ingot, in one heat, in 1 hour on a 150-ton Press.

A 1200-ton Press on cogging 16 by 16 in. ingot to 10 by 10 in., and cutting into 18 in. pieces, averaged 16 tons per hour.

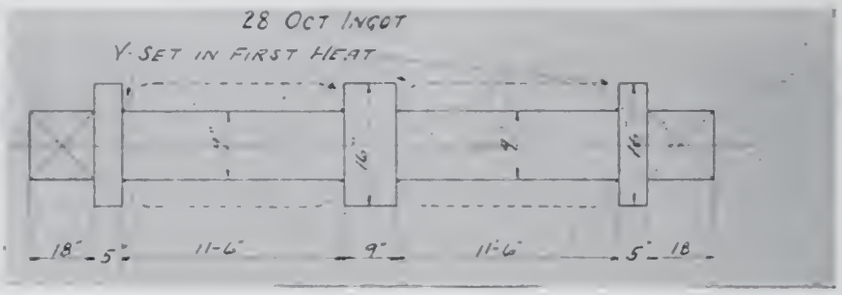

Fig. 35. Three heats: 1 roughing and V-setting, 1 each end finishing. Total time forging, 4 hours.

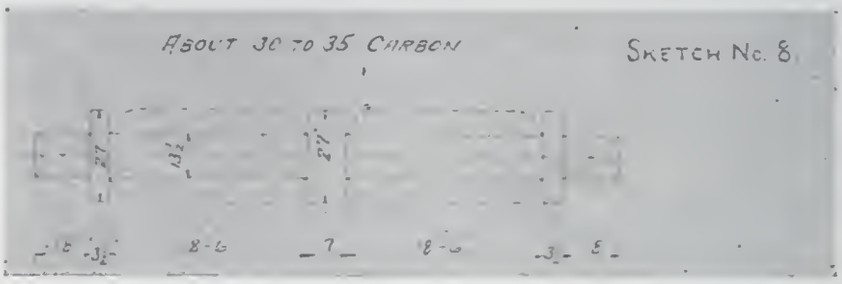

Fig. 36. Thirty-six inch ingot octagonal roughed down to 27 in. and V-set in one heat in 1 hour. Finished one-half in second heat in 2 hours and second half in 2 hours in third heat. Weight 2000 tons.

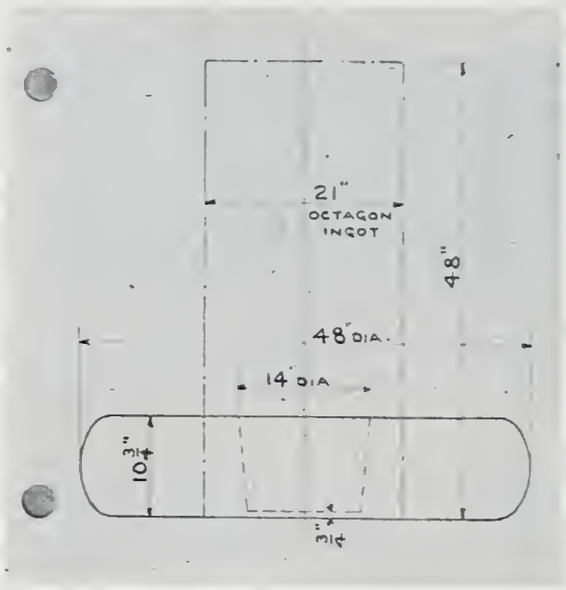

Fig. 37. Piece upset under a 5000-ton Press in one minute.

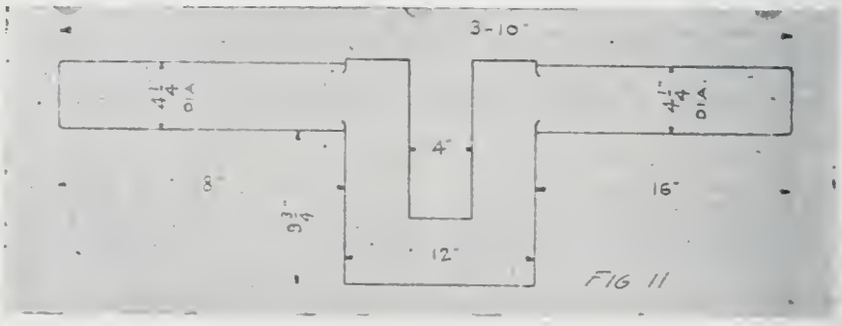

Fig. 38. Shaft forged and slotted in one heat, from 4½ by 14 by 21 in. in 19 minutes, on a 150-ton Press.

high pressures. Of course he mentioned the well-known leather packing. In the higher pressures they sometimes use the hemp stuffing box. How effective is this under 6 000 and 8 000 lb. hydraulic pressure?

THE AUTHOR: In these machines we have been speaking of we use leather packing entirely. But we have replaced the leather packing with hemp packing up to 4 000 and 5 000 lb. With common hemp you get better results than with any fancy packing.

In these machines there are only two packing rings in use, one on the main ram and one on the intensifier. Both of these are *U* packings, from 24 up to 50 in. diameter on the big ones. They run ordinarily about six months on the large ones and on the intensifiers sometimes they will be used up in two weeks and I have known them to run for four months, but ordinarily they have to be changed every two or three weeks. There is nothing special about them at all, simply ordinary *U* packing.

MR. G. E. FLANAGAN: With regard to the ordinary stuffing box packing for high pressures, does the length of the stuffing box vary with the pressure that is used, the higher the pressure the longer the stuffing box—of course within limits?

THE AUTHOR: As I mentioned in the paper, when you get to high pressures with large diameter, the stuffing box depends on the judgment of the designer. With the common every day stuffing box if you keep about 1½ diameters in the small sizes, up to 15 in. you will be pretty safe. If you get very long boxes of course it becomes impracticable. I suppose the longest we make is 24 in. That is not on the presses. We do not use hemp packing on presses, but on large accumulators, the largest we make is a 30 in. accumulator with about 15 in. box, which is not anything like the proportion to diameter of the small ones.

The mistake most commonly made in *U* packings is that the average designer thinks the deeper he makes the leather the better off he is. If you get more than 1½ in. on any size you are getting too deep.

MR. G. E. FLANAGAN: The wear is nearly always near the

bend in the leather, is it not, so that no matter how deep it is made it will not last any longer?

THE AUTHOR: That is right.

A MEMBER: Do you always use the same water in these forging presses?

THE AUTHOR: Yes in these machines we do not change the high pressure water at all. It surges backward and forward. This gives the opportunity to use very pure water to start with and then use a dope, which helps to lubricate it. The only trouble experienced with water is in a very dirty shop. Then some means must be provided for keeping the dirt from collecting on the rods and going into the cylinder. If the rods are kept clean the leather will last a good while. The water may leak a little but you do not have to replace it very often.

MR. L. IVERSEN: The speaker referred to the speed at which these presses are operated. The smaller presses of about 200 tons capacity can make about 200 strokes per min., the larger presses can make about 90 strokes per min. and the largest which are used for ordinary forging purposes of 4 000 to 5 000 tons capacity can operate at about 60 strokes per min. Such a speed would be impracticable for forging work as the large presses make about six strokes per minute when doing ordinary forging work; this is quite sufficient for rapid production.

For planishing work they are, of course, handled very much quicker, but when forging round shaftings, there is generally very little planishing done with the large presses as it is usually cheaper to leave a little more stock on the forging and rough it off in the lathe.

I have seen a 4 000 ton press in Europe forging a 25 in. reversing engine shaft, making the offset for the return throw part perfectly square by means of a *V* set and forging out about 14 ft. of shaft, making a perfectly smooth forging in one heat.

In regard to the steam consumption of these presses, we are told that from two separate tests made on a 2 500 ton press, that they used about 1¼ lb. of steam per ton of press for an average run and they figure that a press uses from one to two

pounds of steam per hour per ton of press; the smaller amount for the large presses. This would make about 4 000 lb. of steam per hour for a 4 000 ton press, while a 1 000 ton press would use about 2 000 lb. of steam per hour. The steam consumption would, of course, depend a great deal on the class of work being done.

If we consider that a 4 000 ton press would do about four times as much work as the hammer "Fritz", which Mr. Ellis referred to, and that this hammer uses about 40 000 lb. of steam per hour, you can readily see that there is quite a saving.

I have seen the actual cut of an ingot forged under a hammer and another under a press and these showed very plainly the characteristics which you have seen here illustrated, except that they show up very much plainer in the actual size.

THE AUTHOR: Mr. Iversen brought up a very good point that I had not thought of before. As far as the working of the press is concerned, some of our younger salesmen tell the same story about 200 strokes a minute and 90 with the big ones. It will do that all right as a planishing proposition. I saw a big 3 600 ton press in England do 40 forging strokes and cut it four to six inches every stroke. They forged a 59 in. ingot into a 22 by 10 in. slab 35 ft. long, cut it in two pieces making each 17ft., picked it up on a traveling crane and put the two pieces away up the shop about 50 ft. and you could not guess how short a time they did that in. It would have been difficult to work this length under a hammer and not shake the end off. They did it in 57 minutes exactly. The actual forging was done in about 37 minutes, the rest of the time being used in planishing. They made a planished job every bit as smooth as we roll it and I asked them when they were planishing or forging to make it as regular as they could so I could check it up and I counted forty forging strokes four to six inches each stroke, and the planishing was very much faster, it may have been 80 strokes.

In reference to the steam used we have no data and nobody knows what it is. We have a 4 000 ton press in England that used 9 000 lb. af steam per hour.

MR. E. K. HILES: I heard a very interesting discussion

recently on the possibility of using forging presses for doing the work of blooming mills. I do not believe it has ever been done but I believe some figures have been made on that sort of a proposition. Of course it would require heavy presses and extensive equipment in the way of tables and manipulators. I wonder if Mr. Ellis will give us any information on this phase of the subject.

THE AUTHOR: I do not know whether I am allowed to give away trade secrets. A forging press will I believe make a pretty good blooming mill proposition within very small limits. On a tonnage of about 200 or 300 tons a day I think it would probably make a good investment. But as soon as you get into high tonnage it would not be a paying proposition. With a small proposition, running say one furnace, you can use a 1 500 or 2 000 ton press, taking a 16 by 18 ingot and reducing it to 10 by 10, and you could do it on a small labor cost. But it would not be advisable to try it on anything that would run over 300 tons.

MR. G. E. FLANAGAN: What are the limits as to size or capacity of these presses?

THE AUTHOR: I do not think there is any limit to how large they can be built. We are willing to build as big as required. They have been made up to 14 000 tons. As far as the large ones is concerned, that is where they shine. When you get down to small sizes there is a limit. I believe a 150 ton press is as small as should be built. There are a number of other types that will do very good work under 150 tons. I do not believe we can compete in very small blacksmith work, in work below 1½ in. square.

CHAIRMAN A. L. HOERR: There have been designed and built hammers of a different type than the old style steam hammer which have been recognized as very economical in operation for certain classes of small work. We would like to hear from some one on the subject of such hammers.

MR. J. A. SMITMANS: The hammer which Mr. Hoerr has reference to is the Beche Pneumatic Power Hammer. The old time power hammers were helve-hammers usually operated by

a water wheel. Later improvements in power hammers consisted in putting an elastic medium between ram and operating mechanism. This elastic medium consists either of steel or rubber springs or an air cushion.

The Beche hammer is an air cushioned hammer. This machine has two separate cylinders, one in which the ram or hammer-head moves, actuated by compressed air and vacuum. The air pressure and vacuum are generated by a double-acting piston in the other cylinder. One of the advantages of this machine is that the ram is not attached to any piston rod. A noteworthy feature is the absence of stuffiing boxes. This power hammer can be run direct by an electric motor, as the load on the operating crank is uniform and not subject to shocks.

Of course, there is a maximum limit to the size of these hammers. The largest hammer of this type that I would recommend has a falling weight of about 1 000 lb.; this would be equal to a 2 000 lb. steam hammer.

In making large forgings, the blow of a hammer will not be effective at the center of the material, as you have seen on the slides shown to-night. For making heavy forgings, as for instance, engine shafts, die blocks, etc., the hammer cannot compete with the forging press, but for general blacksmithing work the hammer will remain the best forging machine.

Mr. C. G. Landes: I would like to ask if this type of hammer is adapted to pressed work such as wheelbarrow bodies and that class of work where they use a hammer.

The Author: The press in all its forms is suitable for just plain pressing work, because you have complete control over it all the time, and it makes a good shear. It shears as high a 5 in. round without any break in the piston rod. That is a remarkable feature about it that you can use it for pretty nearly everything.

Mr. W. A. Keirn: I would like to ask Mr. Ellis as to his idea of the comparison between steam hammer and press. For instance say you would replace a ten ton hammer with a hydraulic press, what size of press would do practically the same work as a ten ton hammer?

The Author: In general 1 000 tons.

Mr. H. E. Cole: I would like to know if there is a work along this line of a press to take the place of a large trip hammer where dies are used.

The Author: There has been a lot of work done along the lines of finding out what can be done. In Germany they are doing a class of drop forgings; but there is such a variety of drop forgings that it is difficult to answer that in a broad way. Mr. Eden is here, may be he can tell you.

Mr. J. A. Eden: On the question of drop forgings, take for example such work as car truck frames, the Brill Company are forging these exclusively under the press but they do not get the same even forging that is gotten from the hammer. We know there is quite an amount of die forging done abroad for the auto trade. We are told the F. I. A. T. Co. has threatened to get all forging abroad unless the manufacturers of this country can give them press forgings. They state the European machine (automobile) has all pressed forgings, and we further understand that they can get all sorts of forgings and of any section. In this country, however, we have not yet been able to make anything in the thinner sections on account of the chilling action of the die due to the relatively slow action of the press.

The Wyman & Gordon Co. have a number of presses with which they do a lot of rough die forging, but all their finished work is made under the hammer. Pieces with any thickness and of symmetrical shape such as gear blanks, can, we think be made in the press to advantage from a billet say four inches high, in one squeeze. Under the hammer this might require 50 blows which would be a decided advantage in time in favor of the press.

In drop forgings I have had some experience and on the press we are feeling our way and have made no actual progress in this country. We know they are making forgings abroad under the press and are sure that we will do the same in this country in time.

Mr. Hutchinson: I would like to ask Mr. Ellis how he explains the difference in structure between the hammered and pressed specimen as shown by the etched pieces. What is the theory?

THE AUTHOR: I believe it is a very simple thing. The hammer you all know, only works on the outside of the material. In other words the hammer works like a piercing machine, it works through the outer fibers to the center and disintegrates the center. The hammer doing very much the same thing, does not have as long to work so it does not get its work in as well. It works toward the center so the outer parts get all the work. With the press it is different. If the end bulges it is working in the middle or it would not flow. It works in that direction and makes the material very dense. It is a matter of making the molecules lie close together and working it all the time all the way through. You can get any amount of etchings that will show exactly the same thing.

I was brought up in a hammer shop. We had the troubles of using a heavy hammer on a light piece or a light hammer on a heavy piece. A heavy hammer will disintegrate the center and with a light hammer you are just flowing the outer edges. With a press you cannot do that. You can work it until it is black and go on working, until you get down to small sections like 1½ in. Even with this we have some samples which we worked from four inches to one inch square and bent them double and flat without the sign of a fracture.

MR. G. E. FLANAGAN: Mr. Ellis gave an illustration of a vertical piece of steel squeezed down to what he called a cheese, 10¾ in. thick. I would like to ask for what purpose that is used, and also incidentally to have him speak of the effect on the structure of the material when you take a rolled bar say six inches diameter and cut a piece off and place it on end in a press and squeeze it down to perhaps four or five inches thick and make a pinion blank out of it. What is the effect on the internal structure of the material?

THE AUTHOR: I do not want to tell you what that disc is used for. It is used in a line of work four or five hundred miles from here which they keep somewhat quiet and I don't believe they would want it told. The fact remains that they are doing it and doing it all the time and it is very successful. It is a new method of making a certain article.

With reference to the action on the steel when you arrange

the fibres as you do when you roll a bar in one direction and upend it and crush it—that particular case was a cast ingot, it was not a rolled bar—I do not think I can tell you the actual scientific result except that I know that by displacing the fibres you get a denser and better material. All die blocks are made that way, and that is the secret of making a good die block, to distribute the molecules until there is no grain. In that particular case the object is to get the outer ring the best worked metal and to get the center of the ingot that is black in the center of the piece and when it is punched it will take that out.

Chairman A. L. Hoerr: I would like to say in closing that you do not probably all appreciate how much Mr. Ellis has done in preparing this paper. We called on him rather unexpectedly as the paper scheduled for to-night was unavoidably postponed and Mr. Ellis' turn had not quite arrived, but he very kindly consented to speak out of turn and present his paper at this meeting on extremely short notice.

THE NATIONAL BUREAU OF STANDARDS AND ITS WORK

By S. W. Stratton*

It gives me great pleasure to meet with you this evening, particularly so as the first talk I ever gave in connection with the Bureau of Standards was before this Society. It was nearly ten years ago. We had not much to talk about then. I brought out some of our historical standards and one or two gentlemen have not yet gotten over abusing us for exposing those sacred relics to your view that night. I might say, however, that they were only relics and had not been used as standards for several years. The criticism grew out of the mistaken notion of some people that a standard is necessarily a unit. A standard need not be a unit. Our standard of length is the particular distance between two marks on a platinum-iridium bar, which is taken as a standard. It need not be a yard, it need not be a meter; but in our particular case the yard and the meter have been referred to it. Hence, in exhibiting to you the particular historic yard, which is of great interest to all of us, we were not exposing to view any current standard of length.

My training happened to be along the lines of mechanical engineering and later I became interested in physics. One of the things that impressed me most in my work in physics was the inertia, if I may call it such, of the application of pure science in our industries—the time that elapsed between the discovery of a principle and its application. I was continually brought in touch with facts that might be used to advantage in the different kinds of manufacturing with which I was reasonably familiar. When the opportunity came to take charge of and organize the Bureau of Standards, I saw at once the means

Presented at the regular monthly meeting of the Society, May 16, and published in the June, 1911, Proceedings.

*Director, National Bureau of Standards, Washington, D. C.

for bringing about better conditions in this respect by making the Buerau a sort of clearing-house for certain kinds of scientific knowledge,—a place where those engaged in the industries could go for the latest data regarding the properties of materials, the best methods of measurement, and standards. The Bureau of Standards has come to be such an institution. It recognizes that in order to fulfill one of its functions—the determination of the properties of materials and physical constants—it must be fully equipped to make measurements of any kind and of any degree of accuracy. These measurements in all the branches are not only essential, but they constitute the greater part of the work in determining these and other properties. Many of the constants which we have been using, and which have been considered good enough for many years, need to be redetermined with the facilities of modern methods of measurement and research. The Bureau has in progress or contemplates many researches of that kind, in order to establish on a better basis many of the constants that are now being used, as well as the determination of new ones required.

I can not go into the details of all the branches of the Bureau's work, but will leave that for the experts of the Bureau. I thought you would be more interested in a report of progress, as it were, since the evening nearly ten years ago when I first appeared before your Society. I hope that from time to time our experts will meet with you and explain the details of any of the definite lines of the Bureau's work. A few lantern slides will be thrown upon the screen, to illustrate what I may have to say.

Those of you who have been engaged to any extent in investigative work in physics, chemistry, or engineering know that one of the first requisites is a shop and power plant, with facilities for designing and constructing apparatus. Hence the first building erected was the mechanical building, or shop, a substantial building 50 by 150 ft., three stories high, the first floor of which is occupied by the power plant including the power, electric generators, pumps, refrigeration plant and other general facilities of this kind. The corps of mechanicians includes

skilled instrument makers, men trained in the construction of precision apparatus and in the working of all kinds of materials. To begin with, only a portion of one floor was given up to the shop, the remainder being devoted to various lines of work which in the future would be taken care of elsewhere.

The second building, built soon after the first one, is a substantial physical and chemical laboratory about 60 by 200 ft. and four stories high. The two lower floors are devoted to physical testing and investigations; the third floor is given over to administrative purposes; and the fourth provides temporarily for the chemical laboratories. Scarcely a problem is taken up in connection with standards or the properties of materials that does not involve work of the chemist. In some instances the greater part of the work is done in the chemical laboratory. This floor provides sufficient space for the present, but the chemical staff of the Buerau is rapidly being increased and a new chemical laboratory must soon be provided.

The third large laboratory built was completed last year. Its dimensions are practically the same as those of the physical laboratory. This building provides space for investigations and tests of structural, engineering, and miscellaneous materials; the metallurgical work will be developed in this building.

At the last session of Congress the construction of a fourth laboratory was authorized. It will be a building similar in size and style to those already built and will be devoted entirely to electricity but will afford additional room for other sections by the vacation of space now occupied in the present building.

There is also a small, two-story laboratory devoted to the liquefaction of gases, the production of high pressures and low temperatures.

The Buerau has three branch laboratories, the principal one being in Pittsburgh.

In standards of length there is first the primary standard, carefully preserved in a fireproof vault and never used except in comparisons with the working, or secondary, standard which is of the same material and construction as the primary. If the secondary, or working, standard should be subjected to any

unusual treatment or if its permanence should be suspected in any way it would be compared with the primary standard. Again, there is the secondary standard which is subdivided. This process of subdivision is one of the most difficult in the science of metrology. There is also a working standard suitable for comparison with end standards, and, finally, the standards composed of multiples of the unit used in establishing base lines and in the testing of engineers' tapes. The problem of building up these multiples is as difficult as the production of the subdivisions.

For comparing one standard of length with another a comparator is used. In this particular case the two standards are placed in a box, the temperature of which is constant within a small fraction of a degree. First one bar and then the other is brought under the two microscopes mounted near the ends of the heavy bar. This support for the microscopes is constructed of the nickel-steel alloy known as "Invar" which has practically a zero temperature coefficient at ordinary temperatures. There is also a comparator designed for the purpose of comparing line standards with end standards, a rather difficult problem, and entirely different than the comparison of line standards with each other and requiring different apparatus.

The same conditions maintain as to standards of mass and their comparison. There is the primary standard, preserved solely as a check upon the working standards, and the construction of the subdivisions and multiples of the unit, no less tedious and laborious than the same problems in connection with length. For comparisons of mass a wide range of balances is necessary, each with a sensitiveness and capacity suitable for the work it is to do. The first of the precision series is a small balance carrying a total load of but 10 grams and sensitive to the thousandth part of a milligram; that is to say, it is sensitive to one part in ten million of its total load. There are also balances having capacities of 100 to 1000 grams, and the largest with a capacity of 20 kilograms and sensitive to one milligram, or one part in twenty million.

The standard troy pound was brought over from England

to this country in 1820 and was prescribed by Congress as the standard to be used by the Mint in coining. It is kept at the Mint in Philadelphia and every year the Assay Commission compares the weights of the Mint with it. At the last session of Congress this standard was abolished and the coinage referred to the standards of the Bureau of Standards, in common with all other measurements of mass throughout the country.

As we pass to the different branches of physical measurements, as, for example, electricity, we find several different quantities to be meausred, each presenting the same problems as to the standards and the means for their comparisons as we find in length and mass. There is the standard cell used in measurements of electromotive force; the silver voltameter, used in measurements of current; the mercury ohm, the primary standard of resistance; and the standards of capacity, inductance, and magnetism. Each of these standards presents exactly the same problems as to primary and working standards, subdivisions and multiples, and the apparatus and methods for their comparison, as the standards previously mentioned.

The mercury ohm is a definite standard of resistance, built up according to exact specifications. It is a laboratory standard and requires for its construction the most precise measurements that it is possible to make in length and mass. When constructed it is unsuitable as a working standard, hence copies must be made of more convenient material, such as metal wires. The construction of these working standards of resistance is an exceedingly difficult one, involving the properties of alloys and difficult problems of manipulation. In this, as in the other cases, standards representing the subdivisions and multiples must be constructed. Special apparatus has been devised for the purpose of comparing these electrical standards with each other, and bears precisley the same relation to such measures as the balance does to the measurements of mass. Formerly it was not possible to obtain as high a degree of accuracy as desired in the construction and intercomparison of electrical standards of the various countries; but great improvement is now being made in this direction. Recently the Bureau constructed three or

four standards of resistance for international comparison. These were compared with the national standards of England, France, and Germany and in no case was the difference greater than one part in a million, and in most cases it was less. This order of accuracy is nearly equal to that obtained in measurements of length and mass; but to obtain it has necessitated a large amount of the most difficult work.

The determination of the value of the ampere is one of the most difficult problems in connection with electrical units, requiring for its solution the most delicate instruments and the highest order of manipulative skill. The most minute precautions are taken in this investigation, even to providing a circulation of water in the coils to remove the heat generated in them while the current is flowing. The values obtained with this instrument are of an extremely high order of accuracy and are taken not only as a basis of all measurements of electric currents but for comparison with the same results of other countries.

The silver voltameter is used as the secondary or working standard in current measurements and its study and development is one of the most important electrical problems now in progress at the Bureau. Two years ago an international conference held at London for the purpose of re-defining the electrical units, a committee composed of members of the staff of the four national laboratories was appointed to prepare specifications of the electrical units and to determine their values. This committee met last May at the Bureau of Standards to outline and carry on their investigations. The wisdom of this plan was soon shown, for by working together and under the same conditions they were soon able to come to a practical agreement; whereas had they worked apart in their various laboratories it is very certain that there would have been a great deal of delay, and the difficulty of securing agreement would have been greatly magnified. During the investigation a great many important questions arose which it would have been very difficult to solve by correspondence, but which were easily settled by the men working together. This case illustrates also the importance of cooperation in such investigations in order

to establish fundamental units on an international basis.

Measurements of inductance and capacity, with which we were unfamiliar a few years ago, have now become very important in connection with telephony, wireless telegraphy and long distance transmission, and the Bureau has in progress at present a large amount of work in connection with the standard methods of measuring inductance and capacity.

There is perhaps no other standard of measurement on as poor a basis as that of light. The incandescent lamp properly seasoned and used at a certain period of its life is used as a secondary standard, as such it is far superior to our primary standards; but it cannot be used as a primary standard as it is not reproducible.

When the Bureau first took up its work in photometry it found that there was not sufficient agreement between the products of the various lamp companies, caused no doubt by a difference in their standards, and that the gas and electric candlepower differed by three or four per cent. By cooperating with the lamp manufacturers and furnishing them with accurate working standards they have been enabled to remedy this defect. Through the efforts of the Bureau, the same unit of candlepower has been adopted by England, France, and the United States. The unit of Germany is different, but it bears a definite relation to the international unit. In addition to maintaining the standards the Bureau has developed methods and apparatus for the rapid and accurate measurement of candlepower and tests commercially all of the incandescent lamps purchased by the various departments of the government.

The variety and complexity of apparatus involved in measurements of heat are no less than those in electricity or the other branches of physical science. The degree is necessarily the same, regardless of the method of measurement; but for each range of temperature there is an entirely different method of measurement, involving totally different principles. There is the mercurial thermometer for ordinary temperatures, some reading almost as high as the point at which the glass softens; thermocouples for higher temperatures, involving measurements

of electromotive force; and optical pyrometers for still higher temperatures, involving optical principles and radiation constants. For low temperatures platinum resistance thermometers are used, depending upon measurement of electrical resistance. Hence, the testing of temperature measuring apparatus includes a wide range of physical principles and methods and they must all be referred to the same standard, the ideal gas thermometer.

The division of heat and thermometry is one of the largest sections of the Bureau's work. Its work also includes the determination of heat constants and the thermal properties of materials, such as specific heats, latent heats, melting points, coefficients of expansion, etc. This data is frequently as important to engineers as standards of measurement, and its determination constitutes an important feature of the Bureau's actives.

The organization of the Bureau is not based upon definite lines of materials, but rather upon definite kind of measurements; that is to say, a material, the properties of which it is desired to determine, would be assigned to experts in the particular field of measurements required. The designation "Engineer of Tests" does not appear in the Bureau's staff.

The heat and thermometry division is equipped for the testing of thermocouples and pyrometers of all kinds. It is also prepared to furnish pure materials of known melting points, to be used in the verification of instruments. It is carrying on extensive calorimetric experiments, in which the different forms of calorimeters are being compared. Investigations are in progress with a view to establishing the heat values of different substances, to be used in the standardization of calorimeters; also the heat values of the constituents of fuel gases. In addition, investigations are carried on for the purpose of securing general values and properties.

Many substances are submitted by manufacturers and others for the determination of their specific properties, it is not unusual for the Bureau to receive a substance, with a request for the determination of one or several of the following properties: tensile strength, hardness, density, heat and electrical con-

ductivities, resistance, specific heat, coefficient of expansion, melting point, and emissivity, etc. In the case of new alloys many or all these properties are needed.

Investigations are in progress with the bolometer, thermopile, and similar instruments, for the purpose of determining more accurately the so-called radiation constants, transparency, reflecting power, and the emissivity of materals.

Among the various investigations now in progress of interest to engineers may be mentioned the following: A study of the electrolytic effects on water and gas pipes, the reinforcing of concrete, conduits, and other underground metal work; the fire resisting properties of materials; determination of stresses in the members of bridges, buildings, and other structures, by means of accurate strain measurements; methods of waterproofing and damp-proofing cement, etc. Tables of conductivities have just been prepared for the American Institute of Electrical Engineers from data secured by the examination of a large number of samples of commercial copper.

The Bureau will continue at its Pittsburgh laboratories (formerly in charge of the Technologic Branch of the Geological Survey) the investigation in connection with the heavier structural materials, including metals, clay products, stone, lime, cement, etc. It is not the purpose of the Bureau to duplicate in Washington the work done at Pittsburgh, but rather to establish a close relationship between the two laboratories. The facilities of the Pittsburgh laboratory are being extended with a view to providing it with a complete equipment for investigations in connection with the above materials. A permanent site and new buildings should be acquired at the earliest opportunity, and the work organized on a scale commensurate with its importance. The ten-million pound testing machine, designed and constructed by Mr. Olsen while the Pittsburgh laboratories were under the direction of the Geological Survey, is being installed at Pittsburgh and will soon be ready for use. This will be properly housed and equipped with the cranes, tools and apparatus for its operation. At Washington two new testing machines of the Emery type are being installed, one of

250 000 lb. capacity and the other of 2 300 000 lb. capacity. While these machines are necessary and useful in many investigations of structural materials, by far the greater part of the data needed by engineers today is not that derived by the use of the testing machine, but by means of the most difficult investigations covering the entire field of chemical and physical science.

The Bureau does not plan to enter the field of commercial testing, especially in localities provided with testing laboratories, excepting in referee work and in the unusual and more difficult tests not provided for in such laboratories.

The Bureau tests a large amount of apparatus and materials purchased by the Government, to ascertain whether or not it complies with specifications; this work, in addition to what it saves the Government by placing its purchases upon an entirely different basis, assists the Bureau greatly in the preparation of specifications, and the development of methods of testing. The benefits of this experience will be given to the public in the form of bulletins, circulars, and other published matter.

It would be out of place at this time to dwell to any great extent upon the plans of the future; but the Bureau earnestly solicits the aid and advice of the engineers of Pittsburgh, and especially the members of your Society, in establishing its work along the lines that will be of the greatest assistance to the industries of our country.

DISCUSSION.

Mr. J. E. Banks: What publications have you in connection with experiments on full sized structural members and riveted details and so on, have you any list that you could send out?

The Author: Our method of distributing publications is a little different from those usually employed. We issue from time to time a bulletin which is made up of papers as they are ready. This is sent to educational institutions and libraries where a complete file of all papers is essential. Each paper is

re-printed separately by number and always kept in stock and these are sent to individuals upon request. In that way the indivudual receives simply the papers he wants. If we send the whole bulletin to an individual he gets a mass of material in which he is not interested. Purposely this work in connection with the strength of materials was left to the last because we wanted to develop first the tools with which to work. Several investigations of that kind are under way but no publications have yet been issued on that particular subject. This work of Mr. Howard would probably come the nearest to it.

Mr. J. E. Banks: In the old work at Watertown Arsenal what publications have you now?

The Author: Very few of them. I would be glad to have you address a letter to me at the Bureau and I will refer it to Mr. Howard. A great deal of good work was done at the Arsenal but it is always hard to get at. We are hoping to correct that by our method of publication by single papers.

Mr. J. E. Banks: What of the work done at St. Louis?

The Author: I could not say. That was published under the Geological Survey and a number of those are out of print. The Survey has turned over to us all they have left.

Mr. J. E. Banks: Is that to come under your department after this?

The Author: The structural materials department, yes.

Mr. T. J. Wilkerson: Will the laboratory you intend to establish in Pittsburgh standardize steel tapes?

The Author: This will probably be done only in Washington. If there is sufficient demand for it here it could be established very well either at the laboratory or in connection with the city. There are quite a number of cities that have copied our apparatus for standardizing steel tapes and made it a municipal affair. We can test tapes cheaper by testing them all in one place, and we have very good facilities for it in Washington. The standard consists of a bar 150 ft. long which must be continuous, and putting the marks on that bar is quite a

difficult task. The tests now are applied for something like 50¢ or $1.

Mr. T. J. Wilkerson: I am connected with the city and that is why I ask. But it takes so much time and causes so much delay to send them to Washington that it would be much better if it could be done here.

The Author: That should be obviated by the manufacturers of tapes. We are encouraging them in cases of that kind to send all apparatus as manufactured from the factory, so that when you buy a tape you can buy it with the certificate of the Department. But any way you ought to send it back occasionally for retesting, especially if it has had much hard use.

DETERIORATION OF MACADAM ROADS AND THE PROBABLE CURE

By Samuel D. Foster.*

Under the name of macadam roads, I expect to class both the road designed by Telford and the road designed by MacAdam.

The Telford road consisted of placing upon the level bed prepared for road materials, a bottom course or layer of stone to be set by hand, in the form of a close, firm pavement, the thickness of this foundation course varying from 5 in. upward, depending upon the material composing the sub-grade and the vehicular traffic it will be called upon to carry. Upon the top of this foundation is placed a course, or courses, of varying sized stone, to form what is known as the "metal surface".

The MacAdam road differed from that of Telford in that MacAdam was satisfied with laying the metal surface directly on the surface of the ground after the irregularities had been leveled, the side ditches formed, and the proper drainage system installed. This metal surface was composed of hard stone broken to a uniform size and cubical in form, ranging from 1½ to 2 in., and was placed to a depth varying from five to nine inches.

As to the relative merits of the two roads, I will not go into detail, but will state that in Allegheny County the greater percentage of our roads have been constructed from a combination design taking the best of the Telford and MacAdam ideas.

Our roadways are graded to a width of 30 ft. In the center of this 30 ft. the subgrade is formed for a width of 16 ft., having a crown of four inches. Upon this subgrade is placed a Telford foundation eight inches in depth, throughout the full width. This foundation is thoroughly rolled by a 10-ton roller, and the

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larger voids filled with small stones. This rolling continues until a true and uniform surface is obtained for the foundation.

Upon this foundation is placed approximately five inches of loose broken stone, either limestone or trap rock, of a size that they will pass through a three inch ring and not pass through a 1½ inch ring. This stone is thoroughly rolled with a roller weighing not less than ten tons, and the depressions filled and raked until the surface is true and even. Upon this sufficient dust or screenings of some cementacious stone is laid as a binding course.

This course is just sufficient to bond the stone and render the surface smooth. The binding course is then thoroughly sprinkled and rolled with a 10-ton roller until the passage of the roller causes no waves in the surface. This binding of the surface stones constitutes the essential feature, to my mind, in any metal road; and in what may be termed the life of the macadam road.

Upon this surface now must come the traffic, the impact, the drag, and the wear of all horses' hoofs, wheels and runners of vehicles passing over it. The impact of a horse's hoof upon the macadam road has a tendency to spawl or crush the stone used in the wearing surface. The wheels of the wagons where the load is greater per square inch than any particular stone is able to bear, will cause the beginning of a rut, and the sliding of the wheel from one stone to another will grind more or less dust from the metal surface. The amtomobile, driven by powerful engines, exerts a force in the rear wheels which causes what we may term a continual slide or scraping. This scraping has the effect of pulling the fine particles of binding material from between the stone and in many cases of loosening the stones themselves and starting what is known as raveling of the roadway. These stones, drawn from the roadway, are quickly pulverized by passing wheels; and the body of the automobile, constructed as it is, passing at great speed over the road, causes a vacuum or heavy draft immediately under the car, which sucks this dust up from the roadway and the wind blows it into the fields. Inasmuch as this dust constitutes the life of the road, it is a

simple matter to figure from the amount, and the kind of traffic over roadways, the life of the macadam road in each particular locality.

While in a great measure we may lay the blame of the deterioration of macadam roads to the automobile, it may be well to remember one point in particular, that it is not so much the automobile itself that is the cause of the deterioration of our roadways, as it is the fact that where one man fifteen years ago would own a pair of horses for pleasure, ten men today own automobiles; where a family several years ago having a team and carriage would use that vehicle for pleasure driving probably once or twice a week, fifteen out of twenty automobile owners today use their vehicles twenty days out of every month during what we might term the season of good roads. So it is not altogether the automobile as much as it is the increase in traffic over our roads that is the cause of this deterioration to such a great extent of what it was a few years ago.

Experiments with a view of allaying this dust nuisance were first carried on in California, and the first asphalt oil used was about the year 1896. In 1898 about six miles were oiled in Los Angeles County, California, with the idea of laying the dust; the experiment was such a decided success that the idea spread rapidly and many miles were soon covered with asphaltic oil. It was then found that the oil not only laid the dust but also bound the dust particles together and formed a tough layer of an asphaltic nature, that acted as a real road preservative. From these simple experiments in California, the idea that there was a chance of preventing deterioration on macadam roads spread all over the country and the many highway engineers who were interested in their work began the investigation of methods for the prevention of this deterioration.

Naturally this investigation was along the line of saving the roads already built, and in the main consisted of applications to, and treatments of, the surface alone. Oils of various grades and containing different amounts of asphalt were soon on the market. The first of these were the natural asphaltic oils of the Texas, California and Kentucky districts, which have

a more, or less, asphaltic base, but at the present time almost all the oil companies have residuum products that are for the most part the study of their chemists and experts. The use of tar as a road preservative dates back to about the year 1886, when it was used in the city of Melbourne, Australia, with a great deal of success. It seemed to bond the road together thus both laying the dust and preventing deterioration. These experiments were continued in several countries, France, England and the United States leading.

At present these road preservatives may be roughly classed under the following heads: Residuum-asphalts, or asphalts obtained from crude oils, Natural asphalts such as Bermudez, Cuba and Trinidad and the tar products.

Experiments have also been carried on with a material named by its inventors "Glutrin", and is made from the residuum of the wood pulp of the spruce tree. It has a tendency to thoroughly bind together the particles of the road and render the surface of the roadway waterproof.

The writer's first experience with oil for use on roads was in 1907, on the Isthmus of Panama, where it was used to lay the dust on the roadways leading through the hospital grounds at Ancon. The oil used was the natural California oil and had a rather heavy asphaltic base. We were successful in what we attempted to do and had little or no complaints from dust thereafter. I have followed very closely the use of oils since that time and have had more or less success in the application of oils for both the laying of dust and the preservation of the roadway. At first, the application of the lighter oils, or what may be termed the road preservatives, looked like a solution of this very vexing problem; and perhaps is for roads over which the auto travel is predominating, as the tendency of the automobile is to iron out the road and keep it smooth. Where this is so the road readily sheds the rainfall and affords very little chance for the frost to do much damage; but, where a roadway is subjected to a very heavy wagon traffic, the horses' hoofs constantly cut into the soft asphaltic surface and the rain has easy access and forms a muddy condition that holds the water and

causes a puddle that eventually breaks the bond between the small surface stones and causes the road to start to ravel. Then again the lighter oils in these asphaltic surface treatments penetrate the road, and in many cases entirely surround the small surface stone with an oily film and in so doing bring about a condition that prevents the road being rebonded and the stones coming loose are quickly crushed into dust.

The experiments carried on in this county have been many and varied; the first were, as stated before, for the purpose of laying the dust which had become such a great nuisance; the idea that the oil had another value that held out a vision of road preservation caused a number of experiments along the line of increasing this value, and I believe Allegheny County has had as much success along this line as probably any other county. Our method consists today of the application of an asphaltic oil running about 50 percent asphaltic base. This oil comes in tank cars and the oil is fluid enough to be readily pumped from the cars, in ordinary summer weather, but during the first few days of each season it has been necessary to apply steam heat to the cars to cause it to flow readily. This oil is pumped into tank-wagons, that hold from 400 to 500 gallons and are provided with a valve and distributor arrangement that allows the operator to govern the amount of flow at all times. The roadway before being treated is swept thoroughly by a horse sweeper and with hand brooms to entirely remove all dust and dirt from the surface. This also loosens the immediate surface and gives the oil a chance to penetrate the road and form a bond. The road is then left to dry by the natural evaporation of the lighter oils, or is covered with small stone or sand, to alleviate the disagreeable condition that sometimes follows the application of this light oil. The work done during the past three years has shown up extremely well and we have cases where the oil has stood an extra heavy travel for a period as high as two years without showing a dusty condition, and this is on such roads as the Brownsville and Steubenville Pikes.

The cost of applying this light oil for the various years since 1907 is as follows:

	1907	1909	1910
Oil material . .		0.01599 per sq. yd.	0.012212 per sq. yd.
Labor	0.0615 per sq. yd.	0.00663 do	0.007086 do
Demurrage and frt. chgs. . . .		0.00018 do	0.000315 do
Supplies, tools, wagons, etc. .			0.001265 do
Averages	0.0615 do	0.02280 do	0.020878 do

The heavy cost during 1907 was probably due to the fact that the work was done by contract. During the years 1909 and 1910, the work was carried on by our own maintenance force, and correct cost data has been obtained.

On the Steubenville Pike, outside the city limits west, granulated calcium chloride was used to allay the dust. Calcium chloride is a chemical salt, white, clean and non-corrosive and is without odor. Its main property when applied to a road is that it immediately absorbs moisture from the atmosphere and holds that moisture in the road, thus keeping the road moist and dustless, and by preventing dust lengthens the life of the surface. It is distributed on the road either by hand or by machine distributor, and costs approximately between three and four cents per square yard during the season. It is necessary to treat a roadway with calcium chloride every four or six weeks, dependent a great deal on the humidity of the air. The main point of merit in this treatment lies in that the disagreeable conditions arising from the first applications of oil are not present where calcium chloride is used; on roadways in close proximity to a number of houses and where there is much travel of a pedestrian nature it might well be recommended. Another point in favor of this material which I have gathered from our experiments is that ice and snow do not remain as long on the roadway and in this way helps to solve the question of slipperiness in wintry weather. These experiments looking towards the prevention of deterioration have been carried on by most engineers with the idea in view of merely tiding over the immense systems of macadam roads already built, until a more satisfactory surface could be obtained. As it was evident from the start that any

application of this nature would not bring about a permanent result, practically all the state highway departments and the large corporations and several universities have been carrying on experiments either along their own lines or under partial supervision from the Department of Public Roads of the United States Gov't., with the idea in view of obtaining a pavement that would withstand the great tractive force of the automobile and still present a surface that would not be injurious to horse travel.

It will not be attempted in this paper to go into the relative merits of brick, or block, construction and the macadam roads, as this paper deals entirely with the macadam road. It was at first thought by engineers that the macadam road was done for, and that a new type of road would have to be studied out, but as experiments went along, it was found that the principle of the old macadam road was right and that a first-class surface could still be constructed under the old general macadam idea and that the fault and cause of deterioration lay in the binding material.

These binders consist of asphalt materials, natural asphalts, Gilsonite products, coal-tar products, and portland cement, and the surface treatment, by penetration method or by the mixing process. The general manner in which the penetration method is carried on is to put down macadam in the ordinary way up to the point of beginning of binding, which had been previously done by water and stone ships. The binder then sprinkled upon the roadway either by hand or by machine distributor. This method has been varied in several ways, as for instance, larger stone have been placed on top and the smaller stone on the bottom of the surface course. The bitumen has been applied to the stone and a layer of sand placed over the bitumen; another where the stone were put on in two courses and the bitumen applied to the surface of the first course and surface of second course. The amount of bitumen varies from ¾ gallon to as much as five gallons per square yard. The use of five gallons, however, was a rare instance. The cost ran from 48c to $1.25 per square yard.

The mixing method may be classed in two types, that of the pavement where the aggregate is carefully graded and the least possible percentage of voids is present, and the type for less heavily traveled roads in which the aggregate is not graded and has a large percentage of voids. In the first type, the materials are broken stone, and sand of graded sizes, mixed so as to form a dense mixture. This aggregate is heated and thoroughly dried and dumped into a mixer in approximately exact proportions, the amount of bituminous material being that necessary to make a mixture of the highest density. These materials are thoroughly mixed in machines, of which there are various types, and placed on the roadway while hot. The results secured by the use of this pavement may be classified with the results obtained from brick or block pavements as to durability, but they have in a few instances proven rather hard and slippery surfaces. This may be obviated by the application of a rough sealing coat.

In the second type, the stones are thoroughly dried, being what is termed "run of the crusher" grade of stone. With this stone are mixed sufficient sand to fill the greater percentage of voids and enough bituminous material to thoroughly permeate the whole mixture. These materials mixed under the second type have been laid both warm and cold and very satisfactory results have been obtained from both.

Another method of surface construction is the penetration method, using portland cement as a binder. The stone is placed on the road to a depth of approximately eight inches and thoroughly rolled with a 10-ton roller, until a true and uniform surface is obtained. Upon this is distributed cement grout of a one-part cement and two-parts sand mixture, and the road again rolled, and allowed to set. This form of roadway has been successful in some parts of the country. The writer had some considerable experience and a great deal of success in the mixing of a concrete pavement of a one part cement, 2½ part sand and five part traprock in Panama City. On this pavement, the mixture was made and placed in the street to a depth of from four to six inches, thoroughly rammed and brought to a uni-

form surface by means of a templet. The uniformity of temperature, however, in Panama may have been in a measure responsible for the success of this pavement. In a Northern climate where the contraction and expansion of concrete must be taken into consideration, it is very doubtful if this form of pavement would be practical.

The experiments in Allegheny County have been carried on along practically the same lines as in general throughout the country. On the Steubenville Pike a bitumen pavement was constructed in which the stones were supposed to be graded very carefully and mixed with a heavy Bitulithic binder. The stones were graded, thoroughly dried, and conveyed into a large roadway mixer, mixing a batch of approximately 2500 pounds at a time. To every ton of stone were added 130 pounds of Bitulithic binder. This material was carried immediately from the mixer and placed in the road by small hand-barrows. It was raked into a true and uniform surface, rolled with a 10-ton roller, and allowed to thoroughly set before travel was allowed to go on the road. This road at the present time does not show any cracks, and gives promise of making an exceptionally good roadway. The one objection seems to be in the nature of a slippery surface; but it is my opinion that as soon as sufficient wear has been placed on the road to cause the stone aggregate to be exposed that this condition will be much improved. The cost for this type of pavement will approximate between 80c and 90c per square yard, according to the location of the roadway.

On the Freeport Road a type of the second class was constructed in which traprock of size, 1½ in. to dust, "run of the crusher", was thoroughly dried and mixed with asphaltic binder, about 110 pounds of asphaltic binder being used to one ton of stone, together with two bushels of sand. A precaution on this work was used by cleansing the stone thoroughly with naphtha before placing the asphalt. This material was placed in the road both warm and cold and like results obtained from both experiments. This material at the present time shows a very satisfactory surface, and gives promise of withstanding the

extra heavy wear of the traffic placed upon it. The detailed costs of this type of pavement are as follows:

Amiesite material, cost per square yard.....	66.25 cts.
Labor cost per square yard, including rolling....	10.17 "
Total cost of placing same on road	76.42 cts. per sq. yd.

On the Lincoln Way Road, just outside the city of McKeesport, a mixture of granulated slag and asphalt tar binder was used. This material was composed of slag screenings ½ in. and under, fine slag dust, asphalt tar binder, and an asphalt residuum oil. Twelve percent in weight of slag was mixed with 7 percent, in weight of slag, of the asphalt tar binder, at a temperature of 300 deg. The ½ in. slag screenings were mixed with two percent, in weight of slag, of the residuum oil at 300 deg. The two mixtures are then combined and thoroughly mixed, and must be placed on the road while hot. This experiment shows a very satisfactory condition at the present time, and seems to turn the rainfall quicker than any of the other experimental work, and gives promise of being able to withstand extra heavy traffic. The costs of this experiment, as near as possible to obtain, are as follows:

A mixture of one ton of material cost $3.02. The cost of the oil was 60c and the cost of labor in mixing, 60c, making a total of $4.22. We are able to obtain approximately 10 square yards to the ton, making a total cost per square yard of 42c. To this add the cost of placing and rolling of 10c per square yard, bringing the actual cost to 52c per square yard. This is by far the cheapest and if it holds up anyway well at all, will make an economical and serviceable pavement.

On the Perrysville Road the penetration method was tested by placing four inches of limestone ballast, thoroughly rolling the same, and applying by hand sprinklers a coal-tar binder to the amount of 3.8 gallons per square yard. Unfortunately, this work was done very late in the fall, and the binder became chilled on striking the cold stones on the roadway and a sufficient penetration was not obtained. Consequently, about twice

the amount of binder necessary was present in the upper two inches of stone and none penetrated to the base. When the warm suns of last summer and very hot days came, very naturally the excess of binder was drawn to the surface and ran into the gutters and made a very disagreeable condition. This was obviated by distributing 1½ to two inches more crushed stone over the road and thoroughly rolling the same. This apparently cured the defect. The cost upon this type of road is as follows:

Tarvia material, cost per square yard	24.5c.
Stone material, cost per square yard	45.6c.
Labor charges per square yard	9.4c.
Total cost per square yard	79.5c.

On our Peoples Road an experiment was made with Kentucky rock asphalt. This material is a disintegrated sandstone, thoroughly impregnated with natural mineral asphalt to a percentage of approximately eight to ten percent. The foundation course of two to three inches of ballast is placed on the road and thoroughly rolled. On top of this one inch of rock asphalt is distributed and thoroughly rolled into the surface. The surface is then raked over with an ordinary rake in order to roughen up the asphalt binder. Another inch or inch and a half of rock asphalt is then distributed over the surface and the road again rolled until thoroughly compacted. This surface presents a rather rough appearance for six weeks or so after construction, inasmuch as this material contains some light volatile oils and does not obtain its initial set until these oils are evaporated. After it has been thoroughly exposed from four to six weeks it presents the appearance of a sheet asphalt pavement, and for some districts where the traffic does not include extra heavy hauling, and for level roadways, this type of surface—with some improvements which we expect to experiment with this coming summer—it is believed will make a cheap and economical road. The cost of this type of road is as follows:

Rock Asphalt material, cost per square yard, f.o.b. cars.....	36.6c.
Crushed stone on road, cost per square yard.....	18.4c.
Labor cost per square yard (including hauling asphalt).....	21.1c.
Total cost per square yard	76.1c.

This constitutes a resume of our experimental work in Allegheny County.

DISCUSSION.

Mr. J. W. Hunter:* When the Highway Department of Pennsylvania was first organized there was but little known about the building of roads except upon the basis of what is known as the Telford macadam or a straight macadam. In each of these cases the macadam was water bound. The advent of the motor vehicle caused the disintegation to a great extent of the macadam system of road building. The roads that were first built in the eastern part of Pennslyvania, commencing in 1889 and 1890 and from there on up until 1903, were all MacAdam or Telford macadam roads. Quite a number of the early roads were built by using the slag from the blast furnaces as a base, covering the slag with limestone in most every case. At that time trap rock had not been used to any great extent. Those roads gave very good satisfaction until the motor vehicle came in general use and even for two years or more after the Highway Department was organized the motor vehicle seemed to have but little effect on the road. The increased use of the motor vehicle, however, soon destroyed the surface of the water bound macadam.

The first roads that were built of stone, or as macadam roads, in Montgomery County were built in Lower Merion township under Mr. Cassatt, who was President of the Pennsylvania Railroad, and at the same time one of the supervisors of the township. The work there was followed by the construction of roads in two other townships, Abington and Cheltenham. These townships issued bonds to pay for their road construction, the first named to the amount of $130 000 within a year.

*State Highway Commissioner. Harrisburg, Pa.

The disintegration of the macadam road surface has caused a search to be made for material that will withstand the motor traffic and at the same time not injure the horse. There are many who seem to think that as long as the road is hard and suitable for a motor vehicle that is all that is to be considered. But that is not so. The road builder must take into consideration all the problems presented and endeavor to construct such a road that will not only accommodate the motor vehicle, but which will at the same time be suitable for the horse-drawn vehicles that pass over a road. How to build such a road is a problem that has been considered and is being considered by road engineers all over the world. The construction of a road surface in villages and towns and adjacent to centers of population should be practically a brick pavement, as it seems to give the best results. The extension of a brick pavement road into the country or rural districts is not as desirable as a great many would have you think. You have to meet the horse-drawn vehicle traffic and a brick pavement is very hard on the horse, much more so than the ordinary macadam road.

The next matter to be considered is the use of a bituminous binder mixed with the ordinary macadam stone. The Department has done some experimental work along that line, but our funds for that purpose have been limited and the work we have been able to do has not been very extensive. We have had some good results from the use of the penetration method, that is, pouring a bituminous binder on the stone after the macadam course of stone has been placed on the road and allowing it to fill, in a measure, the voids between the stones. This material usually requires from 1.5 to two gallons of bituminous binder to the square yard and is applied hot. We have also tried the methods of mechanically or hand mixing the materials, putting the mixture on the road surface either hot or cold. Good results have been obtained from both processes. Some of the bituminous binders that have been used have, after being applied to the road surface, proved to be worthless and consequently the work done has failed. One of the best methods to keep a water bound macadam road from raveling or picking up in dry weather and to

keep down the dust nuisance is to sprinkle the surface with water. In the borough in which the speaker lives the water sprinkling process was used for quite a number of years. Some three years ago the borough authorities decided to use some of the processes or methods recommended as dust preventives, using light oils and resurfacing the road with a mixture of oil and stone, but this past season they abandoned these methods and materials and went back to the ordinary sprinkling wagon. They changed the method of applying the water, however, by having the watering done principally in the evening and early morning, very seldom applying any water in the daytime, thus giving it a greater chance to penetrate into the surface and not be evaporated by the heat. In this way they claim that the dust settling process has cost them less than it did by other methods. It is believed this can only be true where the water is convenient and costs but little. Last season they tried resurfacing about half a mile of street with a mixture of asphalt or sand and so far the experiment seems to be giving good satisfaction, but nevertheless the surface becomes dusty. The dust from the other roads will settle on it and the wind raises the dust and makes it annoying, but not quite so bad as it would be with an ordinary macadam road, which is not kept sprinkled in dry weather.

The Department has also tried the reconstruction or surfacing of some roads with concrete. In two or three cases the concrete disintegrated quickly; in a number of cases, however, the concrete has stood up and shows very little if any wear and no disintegration at all. Last fall a section of road was reconstructed with a mixture of oil and concrete, making an oil-concrete road. The amount of the oil applied was 12 percent of the weight of the other materials and the oil was a special oil prepared by the Standard Oil Company under specifications prepared by Mr. Page, Director of Public Roads connected with the Agricultural Department at Washington. The section of road reconstructed so far appears to give good results and does not seem to be as hard on the horses as some other methods of concrete pavement construction.

The Department also last year as an experiment applied Glutrin to a section of road simply as a dust preventive. The first work was done in May and 0.3 of a gallon per square yard was applied in two operations. This material acted very nicely and kept the dust down until some time in the fore part of October, when it was thought best to try a further experiment and ascertain what results could be had if an additional quantity of Glutrin was applied to the road, although the road was not very dusty. About 0.2 of a gallon per square yard more was applied and in going over the road about two weeks ago it showed but little dust and the Glutrin showed along the sides of the road quite considerably, and even now, after a rain, the material can be seen right along the side of the road to quite a great extent. In addition, the Department is going to apply some Glutrin this Spring to a macadam road that has just been finished, and I believe that for probably four or five months dust will not be a nuisance on that road. In fact, if the right quantity is applied, I think it will last fully a season, if not longer. The cost of Glutrin applied on the road surface is about 10c a gallon or about five cents per square yard.

The Department has obtained some very excellent results in the use of limestone on the road, notably the roads built in Lancaster County with the native limestone. Roads built four years ago have never had any resurfacing and even in the dry season last year in going over the road with an automobile there was scarcely any dust visible. It seems that the Lancaster County limestone has the faculty of absorbing whatever moisture there is in the atmosphere and acts nearly as well as calcium chloride, particularly where there is any degree of shade. In an extended dry spell, as we had last year and the year before, the limestone macadam roads are much easier kept in repair and in much better shape than the stone roads upon which trap rock was used, unless limestone had been used in bonding the trap rock in the reconstruction of the road.

The experiments that have been carried on in Allegheny County I have watched with a great deal of interest. Mr. Foster has been very kind to me and whenever I have visited

your city and had an opportunity we together visited the work under his charge. I believe he is getting very good results from his experiments and I believe they are being worked out along the right lines and that he will continue to have good results.

Now just a word about the law under which the Highway Department is organized. Under the law as first passed all the initiative in the construction of roads must be taken by the Township Supervisors. The Department has been criticised very considerably for building isolated sections of road, but when you realize that the hands of the Department were tied except so far as depending on an application from the Supervisors and the County Commissioners together to start the work. Most all the roads that have been built by the Department, and we have built something over 800 miles, have been built in that way. Under the proposed new law we have possibly about 700 miles of the work already done that will be included in the system of roads proposed by the new law to be known as State Highways and which, under the new law, the State proposes taking over and maintaining. So you see the work that has been done by the State Highway Department is evidently amounting to something in being links in the proposed new system. The Act proposes not only the reconstruction of these roads but after they have been taken over by the Highway Department the State proposes maintaining them until such times as funds may be available to reconstruct and resurface these roads. When they are taken over that will of course relieve the counties and townships of the cost of maintenance of these roads hereafter. The work of reconstruction will be in the hands of the Department entirely and the Department will not have to await the initiative of the supervisors or any one else and the work will be proceeded with systematically and as rapidly as funds are available. The new law proposes an appropriation of four million dollars to commence the work on the main highways and for the maintenance of the roads that have been reconstructed up to the present time, and two million dollars for continuing the work under practically the present system by which the Township, County and State each pay a proportion. The proportion that the

State will pay under the new law is 50 percent of the cost of construction, whereas under the old law the State paid 75 percent, the Township 12½ percent and the County 12½ percent. Under the new law the Township will pay 25 percent and the County 25 percent.

The problem of maintaining the roads or making such roads as will be practically dustless and at the same time waterproof is one that cannot be solved in a day nor a week nor a month nor a year. One of the great questions to be solved is how best to get a uniform binder that will make a good road surface, waterproof and as nearly dustless as possible. For such a product the road builders have to depend upon the manufacturers of bituminous materials, whether they be of the tar or whether they be of the asphalt nature. It is a problem that is worthy of the consideration of the very best men and the very best minds in the engineering line, not only civil but also chemical engineers. There is no man interested in the road building proposition today but who is anxious for all the help he can get from any and every source. It is a problem that is being considered by foreign countries, England, France and Germany, and there are quite a good many things to be considered along these lines because what may be successful in one foreign country may not be such a great success in this country. We know that in England the tars have been used very extensively and successfully by road engineers in their effort to relieve the strain and stress upon the macadam road and to continue the life of such road. As a rule the tars in this country have not been used so successfully as abroad owing, I think, to the climatic conditions of the country and our varying soils. These are things that have to be considered and the best methods ascertained to make our work successful.

There has come to my knowledge within a few days a proposition made by a chemist who has been examining materials for roads, in which he claims to have found by a combination of silica and soda and carbonate of lime and an oil with an asphaltic base, when mixed together and then mixed with the earth or clay from the roads, a means of making a good permanent road

without using a mineral aggregate. I have seen roads treated with a mixture of oils and they have not proved entirely successful. In fact, I know of an experiment made last summer of placing an asphaltic oil on a road surfaced with Mercella shale, which made a fine surface, but in the latter part of January or early part of February the road surface became emulsified and rolled up just as you would gather up snow and roll it in a great ball, the material dropping from the roll to either side until the road today is as rough and uneven as it is possible to make it. If you can imagine yourself in a rowboat at an inlet and a wind blowing strongly over the water you can realize what it is to go over that road in an automobile. We do not know it all, by any means, but we are striving to obtain the best results for the money we have to expend for the building of roads.

Mr. W. D. Craven, Jr.: Just for a few minutes I will speak of some of the old roads. The Roman roads today have presented themselves possibly more in the line of study than any other roads. These roads were first built 2200 years ago. The Appian Way was started in 312 B. C. and is 360 miles long. The construction of the Appian Way is in two courses of flat stone laid in mortar, next rubble well bedded, then a layer of gravel and lime and topped with a dressing of stone. We do not know what the top dressing was as this has long since disappeared. The length of the 327 Roman roads that we know of was approximately 51 300 miles.

Next to the Roman roads on the continent are the roads in Britain constructed by the Romans and which are the main thoroughfares of England today. One road running north and south through England can be traced at the present time. There is also a road running east through England which can be traced.

These roads have been resurfaced from time to time, but the original foundation is still in evidence. These roads were started about A. D. 43 and were laid with irregular stone blocks which formed a rude causeway five to six feet wide. The first English turnpikes were constructed in 1623 over which toll was charged. These turnpikes caused quite a local war in England

and peasants and farmers burned the toll keeper's houses and organized themselves to destroy the toll roads. However, these riots were suppressed by the government. In 1770 there was a total of 530 turnpikes of various lengths in use. In 1737, 250 miles of roads in Scotland were built with a pitch foundation, pitch and gravel being mixed. This is the first we know of pitch being used for road building.

Passing from these old roads to their builders, there are two men we all hear of so often. Thomas Telford, born in 1757, lived at Dumfries in Scotland and constructed a number of roads. He was a mason by trade and afterwards studied architecture. In 1802 he had constructed roads at an aggregate cost of $2 200 000, and during the 18 years of his supervision of road building 920 miles of road were built with 117 bridges, and all completed without a law suit, which means very good construction.

Following Telford and his road building was John Mason MacAdam, born in 1756, who was also a Scotchman. It is not generally known that MacAdam moved to New York when he was 14 years old and lived there until he was 26 years of age before returning to Scotland. In 1816 he began the construction of a great system of roads which now cover England. At one time he had 300 surveyors at work on roads in England. The macadam road construction is made up of angular fragments of hard materials reduced in size and bound in a compact mass. This was always done under pressure in most cases by a stone roller hauled by horses.

I believe the historians say that the age of macadam roads, the alphabet and the printing press was the beginning of civilization. This is true to some extent because civilization begins with good road building. Take the large cities of China, which are paved as well as any of our modern cities. Go out five miles and you get into lanes in which a cart might be used. Another five miles and you get a mule track. Another five miles, or fifteen miles from the center of the city, you find tracks which even a horse cannot travel and couriers are used for transportation, and so we can follow good road construction in

this country from well kept farms and prosperity to neglected farms and poverty.

The elements of which I will speak tonight are divided into three classes, namely: Dust Laying or Temporary Binders, Redressing or Semi-Permanent Binders and Permanent Binders.

I will first speak of the dust laying by use of asphaltic oil. Oils for this purpose are divided into several classes in which the amount of asphaltum determines the method of applying, and the frequency with which it becomes necessary. A 30 to 40 percent asphaltum oil is placed on the road by sprinkling carts, the road first to be swept clean of dust. The method of laying the dust by means of this oil is accomplished by capillary attraction, as a drop of oil will draw to it the fine particles of dust. In some cities, according to the amount of asphalt in the oil, it is put on two or three times a season, depending on the density of the oil and condition of the road. This oil does not prolong the life of a road except that it does retard the action of wash and the blowing of the dust off the surface.

The second grade used as a semi-permanent binder, is a heavier asphaltic oil, containing from 50 to 60 percent asphaltum. This retains the dust by means of a cushion or a film of oil which covers a road. With this oil we find the minute particles of dust are bound very similar to the heavy stone bound macadam roads. Under a microscope you can see every subdivision of the minute particles of dust held together with the asphalt. The application of this oil is used once or twice a year, yet I have known applications to last eighteen months, climatic conditions and travel governing its life to a great extent. The oil is laid using about one-half gallon of oil to the square yard. On top of this oil is laid a layer of screenings or sand enough to take up the surplus oil, after which the surface is rolled forming a covering one-eighth of an inch thick, and it is possible to take a knife and cut a square from the road, which has a rubbery appearance.

Old roads in every case must be swept clean before applying the oil. The cost of redressing a road will run from 15¢ to 25¢ per sq. yd., depending on the haul and labor.

The temporary and semi-permanent binders are usually applied by sprinklers. The oil is shipped in tank cars for economy and easy handling, and is pumped into horse sprinklers, and in most cases, except in extreme cold weather, is applied cold. There is also an emulsifying oil which is an oil that mixes with water. This is a very light treatment and is used in a manner similar to water sprinkling, once or twice a week for a short period and then during longer periods of from two to four weeks. The cost is so small for the given amount of oil to the amount of water used that it is hardly noticeable. It, however, gives a very sanitary sprinkling and is more lasting and cheaper than the water sprinkling. This oil has been used very successfully on city streets, parkways, etc.

The permanent binder is a heavy asphaltic binder, having from 95 to 100 percent bitumen. This binder is applied in a heated state of 350 deg. fahr., and holds the various stone in place, also forming a cushion between them. This binder is not usually shipped in tank cars, but in barrels, and is heated and then applied to the road either by hand sprinklers or mechanical devices. The standard specifications of construction call for a rolled course of 1½ inch stone compressed to four inches. Over this is poured 1½ gallons of binder to the square yard. Then about one inch of ¾ inch stone is spread over the binder, after which this course should be rolled until the waving disappears. Another application of one-half gallon of binder to the square yard is then made and screening spread thick enough to take up all the surplus binder. Then this second course is thoroughly rolled.

I will attempt to explain the advantages of using asphaltic binder to fill the voids. To start with, it is necessary that we use the irregular stone for road construction. We find with power crushed stone fractures occur. These fractures if left exposed to the weather absorb moisture and gradually disintegrate or become round, thus giving an impossible material to properly pave a road. The old Telford and MacAdam roads were hand broken stone, which method breaks the stone with a grain, making very few fractures. On the other hand with

local stone we find that in crushing we fracture all the high points and these fractures will absorb moisture. In using a binder, we find by test that we practically cover from 50 to 75 percent of the stone. The asphalt binder runs between the stones filling the voids and gives a cushion which cannot be obtained in any other way. This is a very important feature, the cushioning of the stone, as it relieves the contact of two stones and the consequent rubbing of their angular surfaces smooth. Tests have been made of brick pavement and water bound macadam pavements, and we find that an instrument registers a much greater percentage of vibration on a road without a binder. A binder also reduces the wear of contraction and expansion, and takes care of fractures. That being the case, and to carry out our line of reasoning, a little further experiment has been made with stone, water bound macadam and a sand and asphaltic mixture, and here we find that the wear is very greatly in favor of the asphaltic and sand construction. Every asphalt street, as we know, has a top dressing or wearing coat of asphalt and sand, generally from 1½ to 2½ inches thick. This is rolled on a base of 2½ inches of stone. To illustrate the pressure exerted and friction on a stone 1½ inches in size consider a road with 1½ inch stone for twelve lineal inches. There is considerable pressure of a wagon wheel rolling over a 1½ inch stone. On the other hand using ¼ inch stone in the same lineal inches, we find that the friction is very greatly reduced and that in place of eight 1½ inch stone, we have forty-eight ¼ inch stone within the lineal length of twelve inches, thus reducing the friction and pressure on the fulcrum point. I call your attention to this because it all has to do with the advantages of using a binder.

Asphalt is not a new material. It was used in Roman construction over 400 years ago for mortar. A great many buildings abroad have foundations where the asphalt has been taken out. This was more or less a natural asphalt that had a great many impurities in it, but the asphalt melted today from those old foundations 400 odd years ago is the same generally speaking as the asphalt you get today. Asphalt being a base material

cannot be manufactured. We have not gone far enough to classify asphalts, which I think is a mistake because even our natural asphalts dug from the earth vary. Mr. Foster has told you about the Kentucky rock asphalt having 8 percent asphalt. Then there are the California and the Trinidad asphalts, which all vary in their chemical composition. All asphalt originated from oil at some time and through the processes of nature, the light oils were evaporated and deposits left which may or may not have absorbed different chemicals from the location from which they derived their supply. Some asphalts have sulphur and others more or less impurities in them. Now, it might be interesting to you to know how we make these binders. We take the natural asphalt oil as it is taken from the well. These oils contain an asphaltic base and through the process of distilling we reach the material termed "binders". The native asphalts have to be cut back with a flux oil. These are taken from their deposits with a pick and shovel and are not pliable in their native state for ready use. The macadam binder pavements are laid very extensively in the East; New England and New York State leading, and the adoption of this standard method of road construction is gradually creeping into the southern territory and the West. The advancement in the New England States is probably due to the appropriations which they have for road building purposes, most of the states having experimental funds set aside from their regular allowance, which enables them to go deeper into the question of binding pavements.

Cape Cod is an example of utilizing local conditions. In this territory there is a great deal of sand and as it was impossible to use ordinary construction in that territory due to the cost for stone, etc., they have within the last few years been building a very credible pavement with sand and enough binder to mix well. The cost of a binder macadam runs from 75¢ to $1.00 per square yard. New York State has more binder work on roads than all the other states put together, unless you include Massachusetts with them. They have carried on a number of experiments, although they stick more or less to the standard binder pavement.

We have followed out the asphalt binder proposition very carefully, and we find that local conditions govern very much the material to recommend. For instance, you would not use a binder that is adopted for northern New York State in New Orleans from the fact that it is warmer in the South and you will necessarily require a firmer binder. Up to the present time we have to be governed by the material we find to be the most satisfactory because many engineers have not been educated along the chemical lines. The next generation of engineers will have to be chemists as well as engineers. The great handicap of the engineers and producers is that they do not get together on standard specifications and this I would particularly call your attention to. The thing to do is to get together frequently and thrash out the mooted points, for the free exchange of ideas does more to set us right than any other form of teaching. The matter of economy today enters into the proposition. A man will say we can build water bound macadam roads for so much money, and yet taking three states last year it has been found that the application of two gallons of binder to the square yard has cost exactly an average of 24¢ a yard over and above the cost of water bound macadam. At the present rate of wear on water bound macadam, the wearing surface is practically gone in two years time. On the other hand we anticipate not less than three years wear, and from that up, with a binder macadam.

Mr. E. C. Brown:* Road making is not in my line, but we have been trying for a few years to find some outlet for our waste by-products, among which ranks first in quantity what is known as ordinary blast furnace slag. We have tried this on two or three pieces of experimental road. The last one was built about two years ago this coming summer in the neighborhood of Youngstown. There is only one point which would likely be of interest in connection with this. We divided the road, which is about half a mile in length, into some half dozen sections and treated each differently as to the thickness of the macadam and the different binders used. The construction work was performed

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under the supervision of an engineer of the Public Roads office of the Department of Agriculture at Washington and that Department will make further observations and issue bulletins on the road. They describe the construction in a bulletin issued some time ago, but of course that does not tell very much as yet as to the wear. One portion was ordinarily water bound, another was bound with the addition of quicklime, a third portion was bound with a by-product of the paper mills, a sulphite liquor in solution with water, and a portion was made of a mixture of fine slag with a by-product tar. This latter portion particularly has merited very favorable comment, although the road in its entirety has stood up very well indeed. A portion was bound with open hearth slag screenings and that I think is quite as good as the other water bound portions. The part that was bound with tar seems especially good and it seems to me we will have to look for a binder of that description or an asphaltic or bituministic binder for either stone or slag macadam. I do not believe the plain water bound macadam will answer the purpose.

Mr. J. W. Hunter: With your permission I will state a little knowledge I have of the results of the use of automobiles. The roads mentioned as having been built in Lower Merion and other townships adjacent to Philadelphia for ten or twelve years did not cost the townships in which they were built one dollar for repairs or maintenance of the road surface. Within three years after the roads became subject to a considerable motor traffic it cost anywhere from $100 to $300 a mile to maintain the surface of these roads, showing that the use of the motor vehicles does have an injurious effect upon the road surface. These macadam roads did withstand ordinary horse-drawn vehicle traffic for the number of years I mentioned, and it indicates that we must try some other plan of constructing roads to withstand motor traffic.

Mr. W. G. Wilkins:* I was connected with the Pennsylvania Railroad about 30 years ago when the first of those Merion Township improved roads were built and while they have

*Consulting Engineer, Pittsburgh, Pa.

got a bronze statue to Mr. Cassatt in the new station in New York, these improved roads in Philadelphia County are, I think, a greater memorial to Mr. Cassatt than the one of bronze. I remember very well that Mr. Cassatt was so disgusted with the roads that he made up his mind that if he could be elected road supervisor he would change it. He was elected and he spent the entire road tax of Merion Township on about half a mile of road the first year. The farmers were up in arms. He was the most extravagant man they had ever heard of. But he kept on and it was not more than two or three years before the farmers were bragging that they had the best roads in the State. Mr. Cassatt was the father of good roads in Pennsylvania. I mention that as a matter of history.

Mr. J. O. Handy:* I understood Mr. Foster to say that in certain road work they had tried portland cement concrete as a bond. I would like to ask whether those tests have continued long enough to show whether the roads were entirely satisfactory when used.

The Author: The portland cement concrete I mentioned was in the penetration method in what is known as the Hassam pavement. It is a pavement of stone put in the road and thoroughly compacted and grouted with cement and rolled a second time before the cement sets. Then it is closed and allowed to have its initial set and it is five or six days before it is opened. This type of road is one used on a motor track on Long Island and is a most successful piece. I think Mr. Page is experimenting for the government on another piece but I have no reports from him

Mr. W. G. Wilkins: Is the concrete pavement in Cambridge, outside of Boston, Hassam pavement?

The Author: They have some near Boston. I do not know whether it is that particular piece or not.

Mr. W. G. Wilkins: The cement in that pavement is I think about 1 to 20. I met a representative of the Hassam Company about three years ago and he commenced to tell me about

*Chief Chemist, Pittsburgh Testing Laboratory, Pittsburgh, Pa.

this proportion and I laughed at him. He said I will show you, and he exhibited a sample piece about the size of a paving block sawed out of a pavement that had been down some years and it looked very good.

THE AUTHOR: They compact their stone with a 20 000 lb. roller before the cement is placed in the concrete. In that way they have the advantage over the hand or machine mix. You can not obtain the same results from mixed concrete that they obtain from this process. The Hassam people are putting in a mile of pavement in this County now in Moon Township, back of Coraopolis, under Mr. Hunter's direction, and it will be open for inspection some time in July.

MR. HUNTER: At Lynn, Massachusetts, I saw a section of the Hassam pavement put down some three years ago and it showed up very badly last fall. The more recent pavement that was put down by the Hassam Co. in the same city looked very good and it was practically upon the strength of the examination made that I agreed to put down the sample piece in Allegheny County.

MR. E. C. BROWN: Will the concrete not make a poor road for horses, is it not too hard?

MR. J. W. HUNTER: It is not resilient enough, I believe.

MR. W. G. WILKINS: Doesn't the roughness overcome the slipping?

MR. J. W. HUNTER: It overcomes the slipping but it does not overcome the hardness of the impact to the horses' feet. But it may answer all the purposes for light driving. It will not answer for heavy teaming. It would make a good road for automobiling, as shown by the track on Long Island. I examined the work on the track a short time ago and while it had cracked to some extent it did not interfere with the motor track and the wheels of the motor vehicle seem to take hold of it better than most any other surface. It is even better than a brick pavement I think for motor vehicles.

THE AUTHOR: With reference to concrete pavement for horse travel, one of the engineers has constructed a street pav-

ing in which he puts down a concrete base faced with a heavy asphalt binder and on top of that a sand cushion, which forms practically an asphalt top that takes away that shock.

MR. W. G. WILKINS: Have you ever tried the experiment of gravel and asphalt? I saw some in Ashland, Ky. The whole pavement was various sized gravel, the first layer very coarse, mixed with pitch or asphalt, then a finer gravel and the top layer was a very fine gravel or sand mixed with pitch or asphalt. It looked like a very good pavement.

THE AUTHOR: The trouble with our gravels in Western Pennsylvania is that we have nothing but river gravel to depend on and there is so much coal and soft sandstone and shale that goes into our river gravel that to use it without an asphalt binder would be practically useless for a premanent road. Last year I put in about 300 ft. in an experiment using river gravel from 1½ or two inches down. That was mixed with asphalt and placed in the road and then about one inch of pea gravel and asphalt binder was used for a top coat and it is today a very pretty road.

MR. W. G. WILKINS: What did it cost?

THE AUTHOR: Between 70¢ and 80¢, depending altogether on location and distance from the railroads. The gravel would be a cheaper roadway if you could get the wear from it. It turns the water better than broken stone, but I am afraid you could not get the wear out of the soft stone in it.

MR. W. G. WILKINS: Why not put a very thin surface of sand and asphalt mixed?

THE AUTHOR: There is a mixture of sand with this gravel. What I am afraid of is the small shale, sandstone and coal.

MR. L. P. BLUM:* There is one side of this question of roadwear that has not been touched upon this evening. I have observed in all macadam roads this general fault; the traffic is concentrated upon a very small proportion of the width of the road. As soon as a little rut is worn the traffic follows along that

*Civil Engineer, with W. G. Wilkins Company, Westinghouse Building, Pittsburgh.

rut, especially on steep grades. Can anything be done which will distribute the traffic more uniformly over the entire width of the road? I believe that some modifications of the usual road construction could be introduced to effect this result. The first suggestion I would make is that, at times there is too much crown placed in the road; the result being that vehicles, following the line of least resistance travel right in the center of the road, naturally avoiding the sides of the road where one wheel would be much higher than the other. If the road had less crown, there would be a tendency to distribute the travel over the entire width of road. On curved roads I think that we should discard the old system of placing the crown in the middle of the road and elevate the outer edge, making a continuous slope from the outer edge to the inner edge. Such a road cross section produces more comfortable traveling and distributes the travel more evenly over the entire width of the road.

Has the last word been said with reference to the use of a different gauge of the rear and front wheels of vehicles? I believe there would be a great advantage in the general adoption of such vehicles. It would probably be impossible to make such a regulation of vehicles compulsory, but if some pecuniary advantage (as for instance, a smaller license fee) were given to the owner of such vehicle, a mutual advantage might accrue to vehicle, owner and road authorities.

Mr. W. G. Wilkins: When they first commenced to improve the County roads not only myself but other engineers made this criticism, which I think if adopted would answer Mr. Blum to a considerable extent. The County has tried to stretch roads out too many miles instead of making them wide enough. The asphalt pavement on Fifth Avenue shows what concentrating the traffic on a very narrow width of pavement does. If the County and State roads were made wider they would last longer. And I think the County with its power to issue bonds in a few years longer could cover the same number of miles and have roads that would have lasted very much longer.

The Author: I might answer that in this way. I agree with both the gentlemen that in the past some of the roads have

been made with too high crowns. The present system of building roadway calls for four inch crown in a 16 ft. road, which is just barely enough to shed the water. Two vehicles will pass extremely well on a 16 ft. roadway. As fast as we resurface the roadways built under the previous administration we raise the outer side and lower the inside.

With regard to the ruts coming in the road from travel, it is pretty hard to teach the drivers to take one side of the road and not go right up the center of it. In the past the condition was alleviated by scarifying and re-rolling it. But under the present system of oiling the roads and putting this asphaltum on the surface, once they are oiled and the small stones become covered with a film of oil it prevents scarifying inasmuch as we can not bond the road after it has been oiled unless you bond it with an asphalt binder. That recalls another matter in favor of these asphalt binder roads. A road built with an asphalt binder can be built with very much less crown than a macadam because it will naturally shed the water quicker, and in this way we get the travel over practically the whole surface of the road.

Mr. W. G. Wilkins: About what does the County pay for brick pavement?

The Author: The first cost per yard is on the average probably $1.25 for the brick alone and a 4 in. concrete base will run pretty close to 35¢. The maintenance department of the County put in a little over four miles of brick last year with the flush curb about five inches deep, six inches at the top and 12 in. at the base, on top of the old macadam road, using that for foundation. That work cost $1.45 per square yard for four miles including the cost of the curb.

Mr. W. G. Wilkins: Would not the maintenance charges capitalized on a macadam road pay the increased cost for brick pavement?

The Author: It may be so, as Mr. Hunter has said, for certain conditions that demand a brick pavement. In country districts I do not think brick is advisable. I have watched horses pretty closely and with a macadam road or any kind of a road

if the horse can get to a clay road it will go there ninety times out of a hundred. How much harder must it be on the horse to go on a brick pavement?

Mr. W. G. Wilkins: That might just as well be used as an argument for cities to go back to a dirt road.

The Author: A dirt road is not a permanent road. It is only good about six months in the year. We have several macadam roads parallel with 11 ft. of dirt road and at any time when the dirt road is travelable the horses will take that dirt road in preference to any other. That is why we are constructing all our brick roads with 11 ft. dirt roads on the side for a summer road for horses.

Mr. W. D. Craven, Jr.: In 1800 there was a road started from Leesburg to Alexandria, Va. It was finished in 1810. I tried to locate the record of this road but in the limited time I had was unable to do so. It was recently taken over by a company to develop a new residential section. The road is 31 miles long and used to be the direct stage line from West Virginia and Virginia through Alexandria to Washington, Baltimore and Philadelphia. From the time the road was abandoned to the present day it has washed away in places about 20 ft on either side of the old road. It was laid with irregular stones, bonded by small pieces of stones. The nearest quarry we located was two miles from the eastern end of the road. They had evidently carried this stone from that quarry. They had no steam engines and very little powder and it must have been all handwork. They had barred the rock and laid this road with a shoulder and gutter for a distance of 31 miles. This road, built in 1800, shows they used more money and had better roads that we have today. Evidently it was built through virgin forests with possibly a house every two or three miles, and it seems to me we are only now getting back to where we were in 1800. They now are going to take up the stone, crush it and make a macadam road.

Why is it that this thing so often happens. A number of citizens came down in one of our Counties and said, "If you will build us a brick pavement through our borough we will

permit you to build 39 miles of road, if not we will stop you by injunction.'' They had lived in that condition of mud in the borough for forty years without complaint. But as soon as the County had advertised for bids for building 39 miles of road they will hold up the building of that 39 miles of road unless the County build this road in the borough. Here is a place where it seems to me we ought to get together. Why can a few citizens get together and hold up important work to benefit themselves either in the matter of raising the price of their land or in some other selfish way, putting possibly half a million people at a disadvantage. It is done very frequently and at great expense to the County in which a good road should go through. Mr. Hunter may have something along this line?

Mr. J. W. Hunter: The answer in a short way to that question is that it is a practical illustration of the fable of the dog in the manger. It is the same all over the State. Nothing has tended to develop a certain selfishness more than the proposition to get good roads. It is the fellow who is not getting the immediate benefit who is opposed to all such improvements. If the improvements come their way they want them and want them right away, sooner if possible.

Mr. L. P. Blum: Isn't there still another side to this question? There is no engineering proposition upon which the public pretends to possess such exhaustive knowledge, as this question of good roads. Every qualified elector thinks that he knows more about good roads and the proper location of roads than the engineer, who has made such work his life study. The public needs to learn that engineering considerations should prevail in the location and ipmrovement of our highways. Unfortunately, there is no engineering subject where real engineering considerations play less part than in the matter of roads.

CORRESPONDENCE.

Mr. C. L. McKenzie:* Through the courtesy of Mr. Foster, County Engineer, as mentioned in his address, a small section of the road surfacing material known as ''Bitoslag''

*Vice President, Duquesne Slag Products Company, Diamond Bank Building, Pittsburg.

was laid last autumn on the State Road at the edge of McKeesport. The road paving over which the surfacing was laid was the existing Telford stone road, laid under Allegheny County specifications. The Bitoslag surfacing was about two to 2½ in. thick and 14 ft wide. About 50 lineal feet of road was covered. The roadway adjoining at one end of the Bitoslag was the stone block paving of Fifth Avenue, McKeesport; at the other end the macadam, or Telford, county road. The latter was repaired and re-surfaced at the same time that the Bitoslag experimental section was put down. At either side of the Bitoslag a dirt roadway, not paved, made up the balance of the full 30 ft. width of the road.

The name "Bitoslag" is a compound of the words "Bitose" and "Slag". The success of the product is dependent in the first place on the qualities of Bitose, which is a so-called asphaltic cement, manufactured by the Ellis Company of Baltimore, under a patented or secret process. It is claimed that Bitose will retain its elasticity, will not become brittle in the coldest weather of this or much colder climates, and will not crack or fracture, either by the contraction caused by cold, or from the blows of passing vehicles. It is claimed on the other hand that it will not become soft, or flow under ordinary pressure when subjected to the hottest summer temperature, its fusing point being over 250 deg. fahr.

The argument in favor of the Bitose is then as follows: Since under all temperatures met in service it retains a highly elastic or rubbery character, any mineral aggregate (crushed stone, crushed slag, etc.) when coated with it and incorporated in it by thorough mixing, will be protected from abrasion of one particle of stone or slag against another, and from vehicle wheels, horse hoofs, etc. It thus becomes questionable whether a very hard, strong stone, such as trap rock, would be of greater value for use in this road surfacing product than a softer mineral aggregate. This point is an important one in most localities on account of the high cost of trap rock or other hard stone.

While not enough tests have been made to arrive at positive conclusions, rattler tests of bricks, or blocks, made of the Bito-

slag indicate that the use of slag gives a product of superior wearing qualities as compared with that made with commonly available stone. The low cost of slag where obtainable makes it desirable to use, providing the resulting product is at least approximately equal in quality to that produced with stone.

The slag used in the State road test was what is described as hard, air cooled, blast furnace slag. The slag is tapped from the blast furnaces into ladles mounted on railroad trucks, hauled in trains by locomotives to the dumping grounds and, while still fluid, is poured over high banks. After cooling and seasoning for months it is excavated, screened and crushed in the ordinary type of plant used in producing ballast and road metal.

The slag was crushed to a size the largest particles of which were about one-half inch, all the material being included down to the finest dust. While this crushed slag was uniformly heated to a temperature of 300 deg, fahr., a quantity of residuum oil was added, equal in weight to two percent of the weight of the slag. The Bitose, after melting and having added to it fine dust of weight equal to twelve percent of the slag, was then added (in the mixer), the weight of Bitose used being about seven percent of the weight of the slag. A temperature of 300 to 325 deg. fahr. is maintained while mixing until every slag particle is thoroughly coated, when the Bitoslag is ready to apply to the road. The only work required in applying is to spread with rakes and roll with a light roller.

In the case of the experimental section laid at McKeesport the manufacturing was done at New Castle. The Bitoslag was cast into small slabs, cooled in water (no damage resulting from the quick cooling) and shipped to the road site. It was here reheated and applied. The equipment and means of handling were crude (except as to the roller) and the cold and rainy weather conditions unfavorable, the ground being wet. Nevertheless the results, as shown after six months of fairly heavy traffic on a grade, during the rain, snow and other weather of the Winter and Spring, seem to be very satisfactory.

First: The surface is fairly smooth, unbroken by any cracks, and furnishes a water tight seal.

Second: It is not slippery and yet shows practically no impressions from the shoes of horses, and no ruts or depressions from wagon wheels. (The adjoining macadam road shows two pronounced wheel ruts extending right to the edge of the Bitoslag.)

Third: The edge of the Bitoslag was not broken or ragged where the wagon wheels have climbed up from the dirt road alongside. It is reported that in some cases the drivers of loaded wagons coming down the hill have used the edge of this road surfacing as a brake, running one wheel on the pavement and dragging the other on the edge of the Bitoslag.

Fourth: The physical condition of the material seems not to have changed in any respect since it was put down. The effects of hot weather conditions, of course, remain to be seen during the coming summer. It promises well judging by appearance during the few warm days since it was laid.

ELECTROLYSIS OF WATER SYSTEM UNDERGROUND STRUCTURES IN PITTSBURGH

By E. E. Lanpher* and L. B. Smith‡.

The water pipe line structures of the City of Pittsburgh, together with the underground structures of gas, electric light, telephone, telegraph and other companies have been seriously damaged by electrolysis, and a large amount of money has been expended, generally with good results, to protect these underground structures from such action. A history of the studies made, the mitigation work done and the results obtained in connection with the Pittsburgh Water Works system, is the object of this paper. There are few phases of water works operation that have been more subjected to theorizing and less productive of practical results than electrolysis mitigation, and inasmuch as in Pittsburgh, something in the line of practical results has been accomplished, this paper will deal more with methods of electrolysis mitigation than with theory.

HISTORY OF PRELIMINARY WORK AND INVESTIGATIONS

In 1900, Mr. A. B. Shepherd, Superintendent of the Bureau of Water of Pittsburgh, started an investigation to determine the cause of excessive deterioration of water mains and water service pipes in certain sections of the city, mainly in the Penn and Liberty Ave. section from 10th to 34th St., and in the Glenwood section. Water mains and domestic service pipes were breaking and developing leaks with an alarming regularity, although the material and workmanship of these pipes were ample to withstand the water pressures. Double extra

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‡Assistant Engineer, Bureau of Water, Pittsburgh.

heavy lead domestic service pipes were, in many cases, rendered useless after being in service less than one year, and holes developed in cast iron main pipes after only two to three years service. Rivets on steel pipes and flange bolt heads were found to be entirely disintegrated. Under the conditions there could be only three possible causes for such deterioration.

First: Chemical action of acids of the soil on the materials of the structures.

Second: Galvanic action of the improperly combined materials of the structures and the materials and solutions of the soil.

Third: Electro-chemical dissociation of the materials of the structures caused by the action of electric currents on certain electrolytes.

Inasmuch as practically all of the damaging action was in the immediate vicinity of the power houses of the Philadelphia Company, which company operated, through its subsidiary companies, all of the electric railways and the major portion of the electric light plants in the vicinity, the conclusion was soon reached that the last mentioned of the three possible causes of deterioration was responsible; that is, that the excessive deterioration of underground pipe line structures of the water works system was, largely if not wholly, due to the action of stray electric currents returning to the power houses of the Philadelphia Company.

The word structures is here used inasmuch as the deterioration was not confined to the water pipes but affected the valves, hydrants, corporation cocks, domestic services, and in fact all classes of underground metallic structures of the water works, and the gas, electric light, telephone and telegraph companies.

It must not be inferred that this electrolysis of water structures started in 1900, for without doubt it started with the operation of the first electric railway power station in the city and constantly increased as the number of stations and the load of such stations increased. However, prior to 1900 no serious "breakdowns" due to electrolysis had occurred, and inasmuch as the water works engineers had been occupied with the ex-

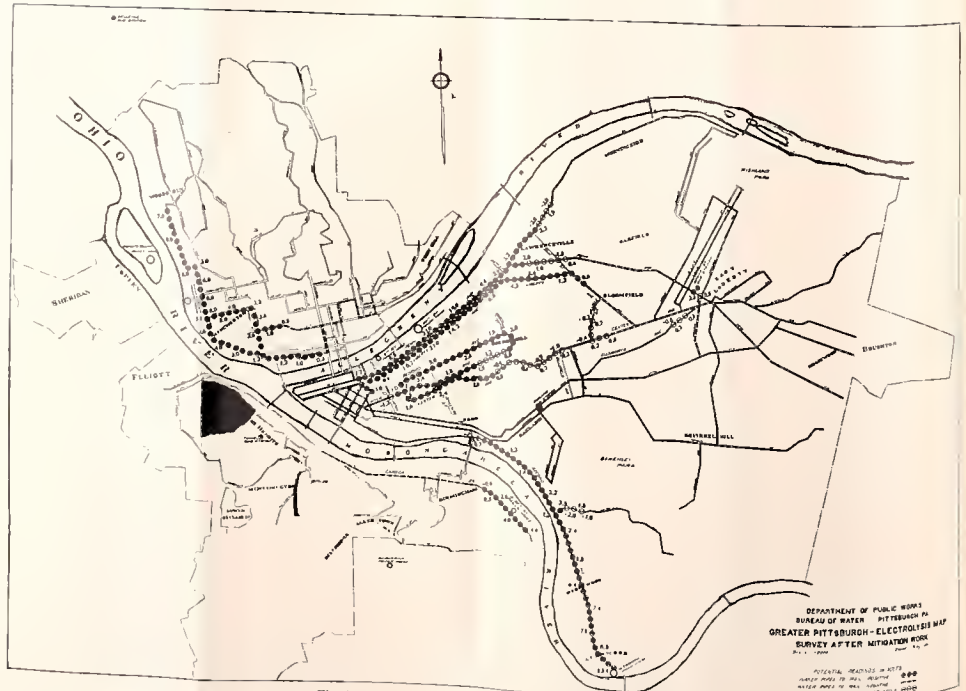

Fig. 1. Electrolysis Map—Survey Before Mitigation Work.

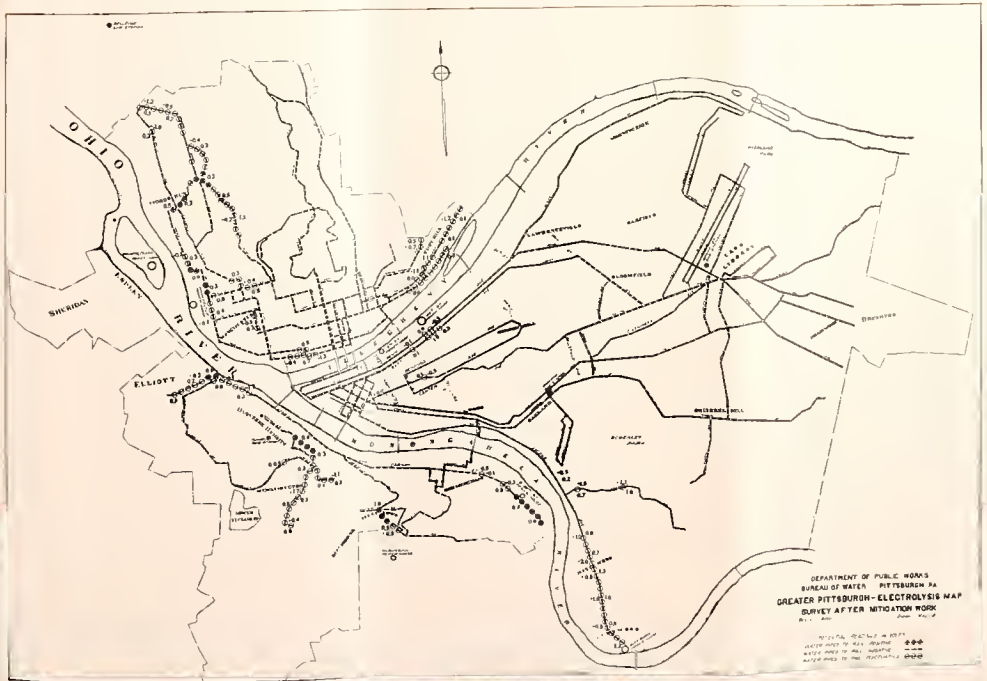

Fig. 2. Electrolysis Map—Survey After Mitigation Work.

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tensive rebuilding and enlarging of the plant, no thorough study of conditions had been made.

The Superintendent of the Bureau of Water, through the Department of Public Works, at once started plans to cause the Philadelphia Company to confine its electric currents to its own structures, or at least to prevent the electric currents from damaging the water system structures. Considerable time was consumed and difficulty experienced in coming to an understanding with the Philadelphia Company as to the responsibility for the conditions. The Philadelphia Company first took the stand that their stray electric currents were not the cause of the damage, but they eventually receded from this stand to take the position that although their currents were damaging the water structures, it was a necessary evil inasmuch as the company possessed charters allowing the operation of the street railways, and were allowed to install a single trolley system, and the current had to return to power houses in some manner, also the rails had been bonded in an attempt to lower their resistance as return feeders; therefore the company had done all that could be expected of it, and that if any current strayed from the rails to the earth and from the earth to the pipe lines the company was not responsible for it. However, in 1905 the city employed Mr. E. E. Brownell, a consulting electrical engineer of Chicago, to make a thorough electrolysis survey of central Pittsburgh, to report conditions and make recommendations looking toward a remedy of the evil. About this time two court decisions were rendered defining quite closely the responsibility of a railways company to protect owners of other property from damage due to returning electric currents, and helped considerably in clearing the differences between the city and the Philadelphia Company, so that they paid for one half of the expense of the investigations of Mr. Brownell and shared in the information obtained. This investigation was started in the summer of 1905, and the report was submitted in September.

This report showed that there were five districts in the central city in which a serious electrolytic condition prevailed. The districts are here given in the order of their extent:

Twentieth Street district, being Liberty Ave., Penn Ave., Smallman St., Pike St., Railroad St., Butler St., and intermediate and intersecting streets, from Garrison Alley to Main St., an area about three miles long and about one fourth mile wide, centering at the Twentieth St. power house of the Philadelphia Company.

Glenwood district, being Second Ave. from Brady St. to the Glenwood power house and a portion of Greenfield Ave.; a narrow strip about three miles long.

Bedford district, including Bedford and Wylie Ave. from Washington St. to Marcella St. and Center Ave. from Fulton St. to Bellefield Ave., the main dangerous area being about one and one half miles long and one fourth mile wide.

Center-Millvale district, being Center and Millvale Ave. from their intersection to the bridges over the Pennsylvania Railroad, at Shadyside and Ben Venue stations.

Broad Street district, being Penn and Highland Ave. adjacent to the Broad St. power house.

Ellsworth Avenue district, being Ellsworth Ave., for about four blocks south of the Ellsworth Ave. bridge.

The conditions of 1905 are best shown by a map of the street railways system of the city, Fig. 1, showing the differences of potential in volts between the water mains and the street car rails as they existed at that time. Difference of potential where the direction of flow of the current was from pipes to rails is referred to as positive; where the opposite direction of current flow prevailed, negative. Districts in which the differences of potential are positive are referred to as positive or dangerous districts; where the opposite condition prevails, negative or safe.

The maximum readings of positive difference of potential were at 20th St. and Liberty Ave., 20th St. and Penn Ave. and near 21st St. and Liberty Ave., being 21 volts, and the differences of potential were gradually less in easterly and westerly directions from 20th St. until they became negative at Main St. and at Garrison Alley. In the Glenwood district a maximum of 14 volts positive difference of potential was found near

the end of the water pipe system near the Glenwood power house, and this difference decreased in a westerly direction along Second Ave. to Brady St. where it became negative. In the Bedford district a maximum of five volts positive difference of potential was found at Bedford and Devilliers St., and this difference decreased to a negative difference at Washington Street, and at Bellefield Ave.

The three other districts were small in extent. In the Broad Street district the dangerous area was only about three city blocks long, although a maximum positive difference of potential of two volts was found about one block from the Broad St. power house. In the Center-Millvale Ave. district and in the Ellsworth Ave. district the difference of potential oscillated from about one volt negative to about one half volt positive.

While it is true that the amount of deterioration of an electrode is proportional to the amperage of a current rather than to the voltage drop, it is true that in the case in question the district of high positive potential so closely conformed with the district of high amperage of return currents that in the positive areas, the extent of deterioration conformed closely with the extent of the voltages.

This survey showed that the greatest electrolysis of water structures had occurred in the 20th Street district, although the damage was extensive in the Glenwood and Bedford districts. Service and water lines in these districts were in many cases entirely eaten through, the deterioration generally starting as a pitting and then spreading. In the 20th Street district, where plumbers were reaping a harvest in repairing service lines, there was a wide spread discontent among the property owners. The Bureau of Water has a record showing that private property owners in this district in one month of 1906 expended $480 for repairs to service lines damaged by electrolysis, and this amount represents only a portion of the expense met by the owners for that month inasmuch as many repairs were made for which the Bureau of Water could obtain no data. The 36 in. cast iron water main on Liberty Ave., which is one of the two important feeders of the Point section of the city, showed such dangerous

pitting that a continuous patrol was maintained from 12th to 34th St. Scarcely a day passed without a break in the mains of this district and conditions in the Greenfield district were almost equally alarming.

Strangely enough the lead joints of the cast iron mains showed little deterioration, nor was there much evidence of deterioration of cast iron pipes caused by the current shunting around lead joints.

This survey showed that about 480 amperes of current were brought into the 20th St. positive district by the water pipes, this in addition to about 2340 amperes of earth currents passing over the water pipes to the rails in vicinity of the power house.

This report recommended, by way of mitigation: First: The bonding by means of copper cables around every caulked pipe joint, principally in the positive areas. Second: The connecting, by means of copper cables, of the mains in various places with the negative bus-bars of the power houses in order to relieve the mains of excessive current at those points, that is, to remove harmlessly from the mains the returning current at points where the resistances were such that the current was leaving the mains for the earth and the rails. This report is recommending this system of mitigation did not overlook the so-called double trolley system but set it aside because of the expense attached to its installation.

After the report was submitted the city renewed its efforts to have mitigation work started at once, taking the position that the Philadelphia Company should select its method of mitigation and proceed in any manner that it saw fit provided only that it did not further endanger the water supply, and that the Philadelphia Company would be entirely responsible for results obtained. Again the Philadelphia Company insisted that the method of procedure should be decided by the city, and therefore that the city should be responsible for all results. The Philadelphia Company finally decided to go ahead with the work on its own methods, and in August 1906, the work was started, contract being entered into between the Pittsburgh Railways

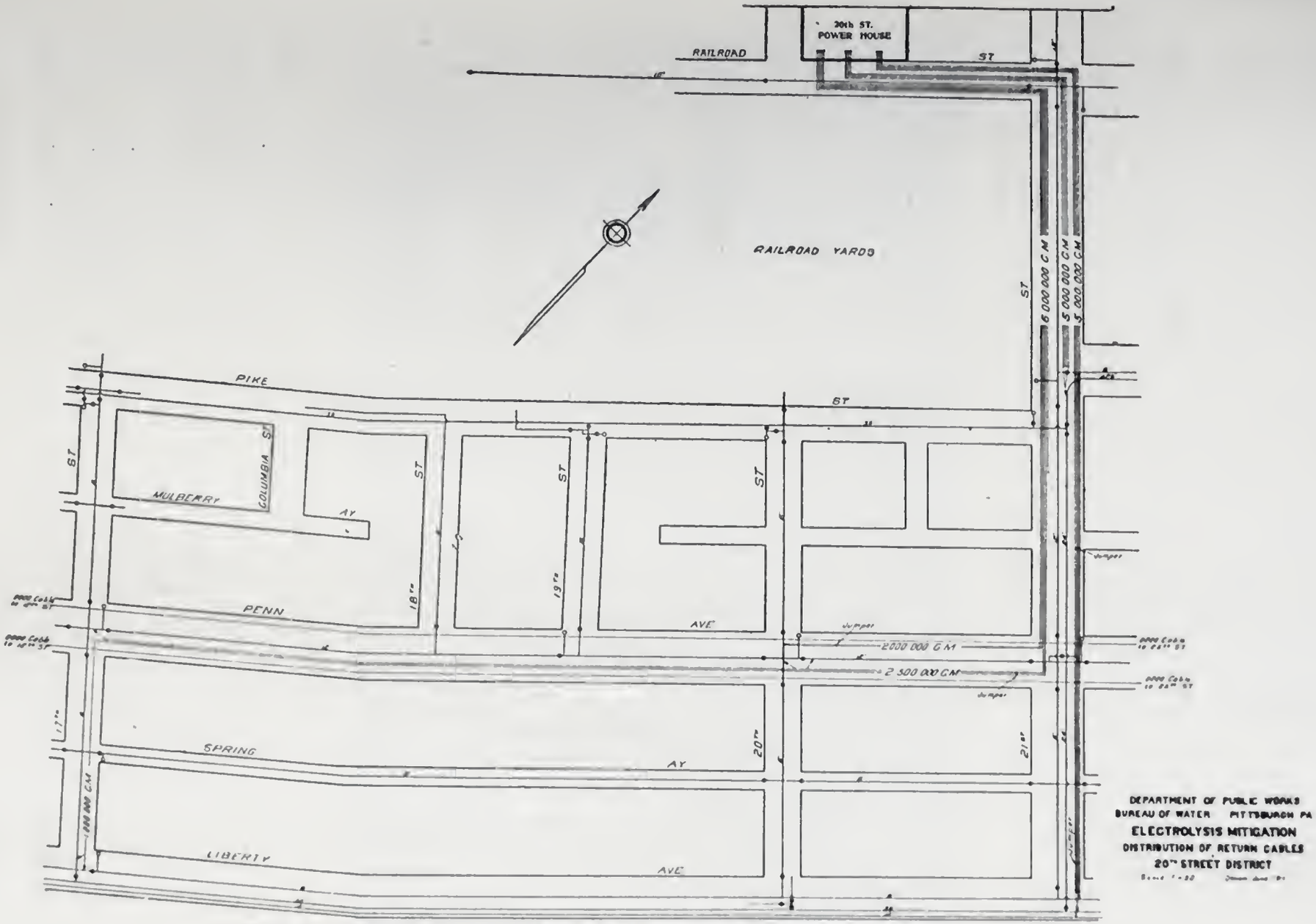

Fig. 3. Distribution of Return Cables in 20th Street District.

Company and Mr. Brownell whereby Mr. Brownell agreed to execute the installation of the Return Pipe Feeder System in Pittsburgh, using the gas mains of the Philadelphia Company and the city water mains as return feeders.

The difficulties experienced in starting mitigation work are herein given in detail inasmuch as similar difficulties must be met in nearly every case where mitigation work is contemplated.

DESCRIPTION OF ELECTROLYSIS MITIGATION METHODS

The city was represented on the work by the Engineers of the Water Bureau for the purpose of obtaining a record of the work done, assisting in the location of water mains and seeing that the water supply was not interfered with. The only actual work, other than record work, done by the city employes was that of tapping the water mains for the insertion of electrolysis contact plugs; this being done by the city drillers with the corporation cock insertion machines.

Mitigation work was started in the 20th Street district and inasmuch as the methods here followed were characteristic of methods used elsewhere in the city a full description is here given.

A resurvey of the district was made and the conditions as compared with the conditions of 1905 were found practically unchanged as to extent of positive areas although the positive differences of potential were, in general, higher.

The main power house of the Pittsburgh Railways Company is at 20th and Railroad St. Within three blocks of this power house, and running east and west, are several large water supply mains leading to the business section of the city, see Fig. 3. These mains include a 42 in. steel conduit, a 36 in., two 12 in., a 10 in. and some smaller cast iron, lead caulked mains. The 42 in. steel main ends at Smallman and Twenty-first St., where a 36 in. cast iron main runs down Pike St., and a 24 in. cross-connection to the 36 in. main on Liberty Ave. is made. In addition there are several large gas mains paralleling the water mains. These mains, particularly the 42 in. steel riveted main,

formed excellent conduits and the problem was to remove the current from them without damage. Two instances of corrosion on large mains are shown in Figs. 4 and 5.

The greatest positive difference of potential or "dangerous peak" of the district, as shown by the survey of the previous year having been at 20th and 21st St., these points were first attacked. A conduit was laid from Liberty Ave. along 21st St. to Railroad St., thence to the power house, a distance of about 1250 ft. Eight copper cables of 1 000 000 cir. mils each were

Fig. 4. The 42 inch Steel Main in Smallman St. at 28th St., Nov. 30, 1908.

first "pulled" in this conduit and all were controlled by switches and attached to the negative bus-bar of the power house. Three cables were connected to the water and gas pipes along 21st St. at Liberty and Penn Ave., Spring and Mulberry Alleys. These connections were made by inserting a plug in the main after the manner of and by the same machine used in inserting corporation cocks or ferrules. The insertion end of these plugs was identical with the insertion end of the city standard ¾ in. corporation cock, except of course there was no water way. The

tops of plugs were flared to 2½ in. diameter and faced to form a contact plate. This contact face was tapped out for the threads of the insertion chuck of the drilling machine and for the bolt holding the upper plate in place. The upper plate was of the same diameter as the contact face of the plug and forming a part of this plate was the socket into which the cable was soldered. The faces of the plates were tinned before they were bolted together. This terminal plug, shown in Fig. 6, and a slightly smaller one for smaller cables was used in making connection to all cast iron water pipe. The terminal plugs used on the gas pipes were slightly different in that they were inserted by hand. The other five cables were attached to a flange of the 42 in. steel main at the corner of Smallman and 21st St., about 700 ft. from the power house. These connections were made by placing between the bolt heads of the flange bolts and the flange, contact plates similar to the upper plate used on cast iron pipes. The paint was removed from the flange and the steel surface faced as much as possible and tinned, and the bolts set up. This was done under full water pressure of 85 lb., one bolt only being loosened at a time.

By November 7th, these eight cables were in place, and the pipe switches were thrown in and a test was made. While the station load was about 12 000 amperes and the current returning over the pipes was about 4600 amperes a positive difference of potential from pipes to rails at Liberty Ave. and 21st St. of 1.8 volts was obtained as compared with 24 volts obtained the following day with the pipe switches out, and 21 volts obtained in the survey of 1905. The differences of potential were correspondingly cut over the entire positive district, except in the vicinity of Liberty Ave. and 32nd St. and west of 21st St., where the cut was not quite as decided as at other points. The difference of potential from rails on Liberty Ave. to rails on Penn Ave. and from pipes on Liberty Ave. to pipes on Smallman St. from 27th to 32nd St. were very high, particularly the readings from rails to rails. The pipes of the section below 21st St. were positive to the pipes above 21st St. and their excess current was crowding over into the section above 21st St. Again

the drop over the cables along 21st St. to the power house was high being about 7.5 volts.

These several conditions prompted the following actions:

Two 0000 cables and one 500 000 cir. mils cable in a three inch wrought iron conduit on 32nd St. were connected by sweating to the 42 in. steel main and by terminals to the gas pipes at Smallman St., and to the water and gas pipes at Liberty Ave., but these cables were later removed because of changed loading conditions due to the starting of the "Express Cars" on Liberty Ave. and to the effect of later mitigation work done west of 21st St.

Fig. 5. The 36 inch Cast Iron Main at 20th St. and Liberty Ave., July 23, 1905.

Two additional 1 000 000 cir. mils cables were installed from the negative bus-bar to the 42½ in. steel main at Smallman and 21st St., making seven cables in all to this point.

Two additional 1 000 000 cir. mils cables were installed from the negative bus-bar to the gas and water pipes at 21st St. and Liberty Ave. making five cables in all to this point.

This work was completed on December 6th, 1906, and with

a station load of about 14 000 amperes and when the ground was unusually saturated with water the difference of potential from pipes to rails at Liberty Ave. and 21st St. oscillated from 0.6 volts positive to 0.4 negative; above 26th St. the differences were uniformly negative; below 21st St. there was a positive peak at 17th Street of 3.8 volts.

It is interesting to note here that it required eight 1 000 000 cir. mils cables to reduce the 21st St. peak from a positive difference of potential of 24 volts to 1.8 volts, and it required four additional cables of 1 000 000 cir. mils each to reduce this difference of 1.8 volts to practically ½ volt oscillating difference of potential.

The positive peak at 17th St. was next attacked; considerable difficulty being experienced in obtaining satisfactory results, due mainly to the high resistance of pipes along Penn Ave. and to the effect of the operation, for about five hours each day, of the power station at 13th and Etna St. to reinforce the 20th St. power station. The operation of this station caused a slight shifting of the positive peak and at the same time increased the positive differences of potential in the section. The connecting of 2 000 000 cir. mils of cable from the 20th St. power house to the pipes on Liberty and Penn Ave. at different points from 20th to 17th St. did not materially reduce the difference of potential at the peak but did have the effect of lessening the current returned to the power house over the seven cables from the end of the 42½ in. steel main, so that two of these cables were disconnected, one finally being used to reinforce one of the overloaded cables running from 21st St. and Liberty Ave. to the power house, and the other was used to connect to pipes on Penn Ave. below 21st St. The high resistance of the Penn Ave. pipes caused the installation of two 0000 cables from 12th to 25th St., connecting to the pipes at several points and to a 1 000 000 cir. mils cable on 12th St. from the pipes on Liberty and Penn Ave. to the 13th St. power house. Before the maximum positive difference of potential of the district had been reduced to less than 0.5 volts a cross sectional area of copper of 5 000 000 cir. mils had been extended from the

negative bus-bar of the 20th St. power house to the pipes at Penn Ave. and 17th, 18th and 20th and 21st St., a portion of which extended to Liberty Ave. and 17th St.; this in addition to the 11 000 00 cir. mils of cables to pipes on 21st St., the 1 000 000 cir. mils cable on 12th St. and the two 0000 cables on Penn Ave. previously mentioned.

Some of the cables were found to be carrying much more current than others running between the same points and jumpers were installed to equalize the current. At a few places the current tended to shunt from one parallel pipe to another and cables were installed to connect these pipes.

When the mitigation work in this district was completed, about February 1st, 1907, there was no positive difference of potential greater than 0.5 volts between pipes and rails even under extreme conditions of loading. To obtain this condition about 86 000 pounds of copper cable was required, mainly accounted for by the nineteen cables, aggregating 17 000 000 cir. mils leading from the pipes to the negative bus-bars of the two power houses but without doubt the greatest factor in the scheme of mitigation was the 42½ in. riveted steel main, the cross-section of which was equal to about 8 270 000 cir. mils of copper as a conductor.

It should be noticed that before mitigation work was started the amperage of the current leaving the pipes in this positive district was about 2800 while after the return pipe feeder system had been installed this amperage had increased to about 5000.

The current from the pipes in the Bedford district was returned through a cable suspended from the 17th Street Incline Railway framework, thence along Liberty Ave. to 21st St. to the 20th St. power house without affecting the conditions of the 20th Street district.

The mitigation work in the other districts followed in practically the same manner with practically the same results obtained as in the 20th Street district. In the Glenwood district considerable difficulty was experienced inasmuch as the pipes were small and old and showed high resistance, necessi-

tating the running of paralleling copper cables in many instances. Also in this district many cases of poor bonding of rails, particularly at steam railway crossings, were found and these were "bonded over" by copper cables.

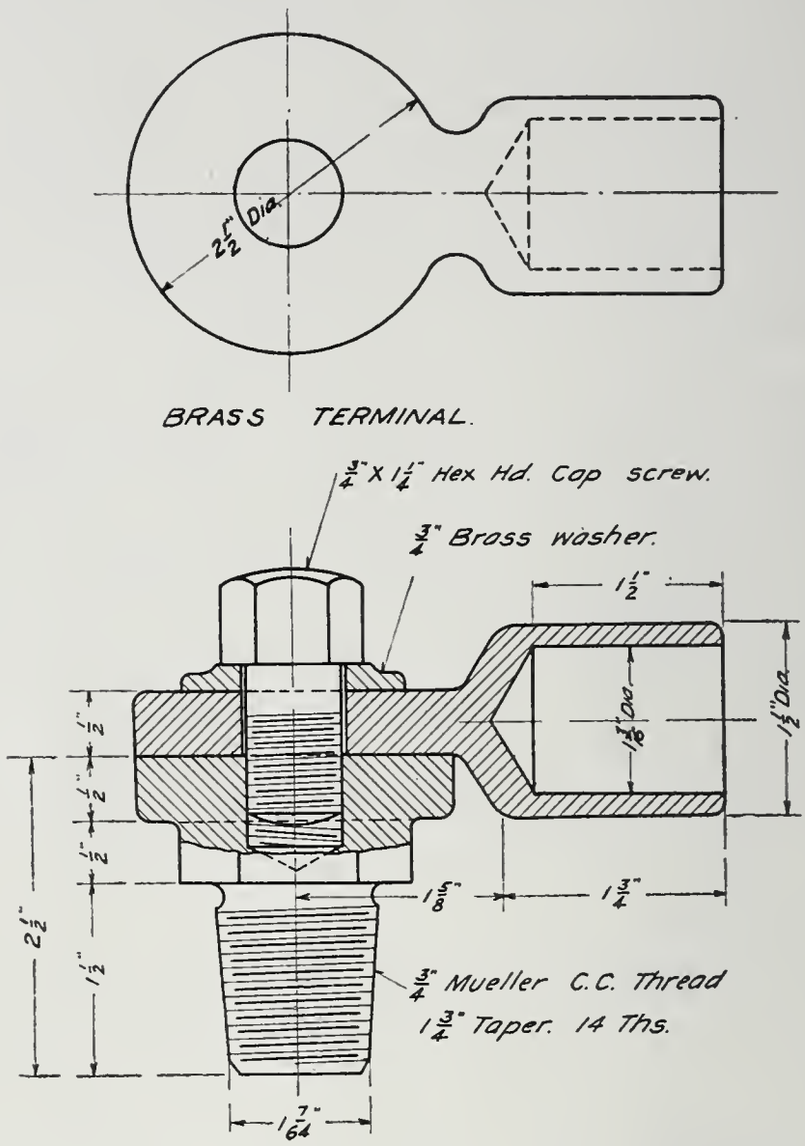

Fig. 6. One Million Cir. Mils Electrolysis Contact Plug for Cast Iron Pipe.

As the work was nearing completion in the autumn of 1907 many complaints were received from the Peoples Gas Company and the Telephone and Telegraph companies, whose structures had not been protected, that the bonding work done had so far increased the conductivity of the piping systems of the water works and the Philadelphia Company that the shunting of current from the unbonded structures to the bonded structures had increased to an alarming extent with the resultant damage particularly to gas pipes and lead sheathed cables. The city

again took the stand that the Philadelphia Company could protect the structures of these companies even to the extent of bonding their pipes and cables to the city water pipes providing that the Philadelphia Company took the full responsibility for the results and the work was finally done.

In July 1907 it became necessary to protect the new 36 in. riveted steel South Side supply main at Carson and South 30th St. by connecting the main and the negative bus-bar of the South 30th St. power station by means of five 1 000 000 cir mils cables. This main had been in the ground less than one year, had been thoroughly coated with mineral rubber coating, but showed many electrolysis pits that extended one third of the distance through the 3/8 in. of steel, see Fig. 7.

Later still considerable work was done on the North Side following the consolidation of the cities of Allegheny and Pittsburgh. Previous methods were followed although, because of changing conditions, the means were considered as temporary in character and the work soon must be reinforced.

PRESENT CONDITIONS

The station loads have increased so that in 1911, at a few scattered points the positive differences of potentials have advanced to above 1.0 volts and action must soon be taken. Comparing the conditions of 1905 and 1911, see Fig. 2, the large positive areas existing before mitigation work was done are very much contracted or entirely eliminated and the positive differences of potential are only a small fraction of their former magnitude.

During the four years that have elapsed since mitigation work was completed in the central portion of the city frequent surveys have been made; plaster casts of certain electrolysis pits have been made yearly; certain lead joints have been exposed and examined at intervals and every pipe break in the former positive districts has been examined carefully to determine whether or not it could be traced to late electrolytic action. It can be said in favor of the mitigation results obtained that the Bureau of Water knows of no water structure

upon which electrolytic action has extended since the mitigation work was finished, nor has the examination of pipe joints revealed a deterioration of the lead, nor is there indication of deterioration due to the shunting of current around lead caulked joints. Without doubt the electrolysis of underground water structures is progressing throughout the present positive areas but that action is and has been too small to be discernable even under careful investigation. The evidence of four years experience in Pittsburgh points to the conculsion that with the

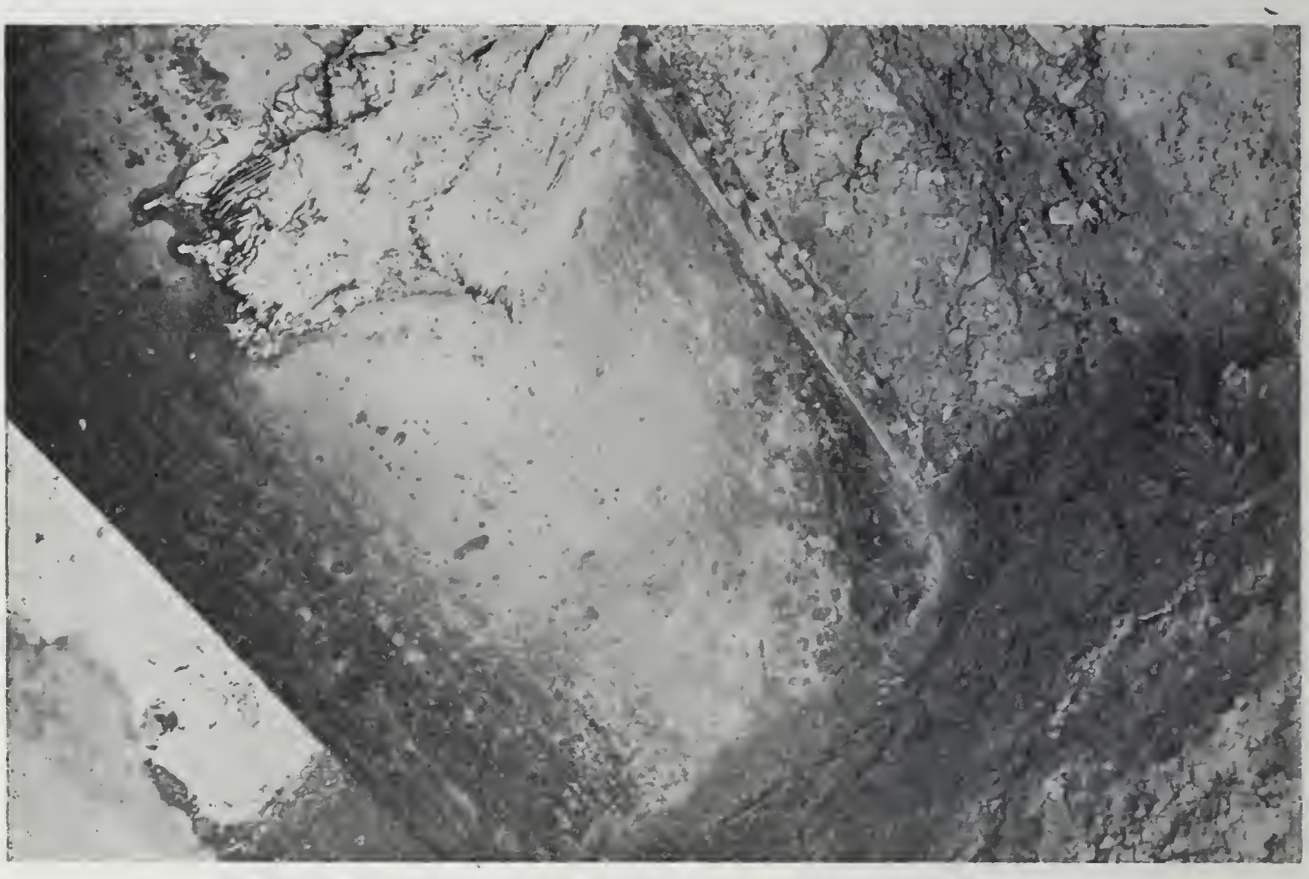

Fig. 7. The 36 inch Steel Main at Carson and South 30th St., July 8, 1907.

pipe return feeder system installed as thoroughly as it was installed in 1906 and 1907 in central Pittsburgh, with such system maintained to meet the changing conditions of loading and pipe distribution, the electrolytic deterioration of water works underground structures has been so retarded that these structures will not fail from such deterioration before they have become obsolete and useless from other causes. This conclusion is based solely on the experience of the past four years and of

course is subject to revision in light of possible but unexpected future failures.

THEORY OF CORROSION

Various logical theories of the corrosion of cast iron and steel have been offered, chief among which are, the carbonic acid theory, the hydrogen-peroxide theory and the electrolytic theory. This last was first propounded by the Swedish physicist Arrhenius in 1877. It has been more fully tested and amplified in recent years so that it has now become the most generally accepted explanation of the dissociation and decay of metals whether traceable directly to a transit of electric current or to a simple galvanic action (local-electrolysis).

Briefly it has been proven that metallic substances are somewhat soluble in water, in the case of iron the iron ions exchanging with hydrogen, that the dissolved portions are then acted upon by the liberated oxygen and that the neutralization effect produces in each action a passage of electrical charges. Messrs. Cushman and Walker of the U. S. Department of Agriculture by means of their ferroxyl indicator show very neatly these positive and negative changes as blue and red nodes accompanying the process of corrosion. Since an acid is by definition a substance containing hydrogen which it easily exchanges for a metal thus liberating hydrogen ions, all acids are therefore active agents of corrosion.

Due to the imperfect mixture of the compositions of even the best iron and steel, positive and negative points are always present so that in the presence of oxygen pitting will take place from the transfer of the inherent electric charges and local-electrolysis occurs independently of current from an outside source.

A pipe in the ground and the metal of a rail form the electrodes of a large galvanic cell of which the damp intervening earth is the electrolyte. The conductivity of the electrolyte, of course, varies with its degree of wetness and character or chemical composition. In the presence of an electric current clorides, nitrates and sulphates are dissociated and at once attack the anode or positive electrode. It is true that at points

where current is leaving the track deterioration of the rails themselves must take place but due to their form and ordinary serviceable life from other causes the problem has not called for the same attention and anxiety incident to pipe line structures.

The cathode being immune from attack electrolysis can occur only at points where current leaves a pipe but the danger points may be where either the whole or a small part of the total current is shunted, and the same current may reenter a pipe and cause equal deterioration at innumerable points of departure.

Fig. 8. The 60 inch Steel Main in Sharpsburg in Clay St., near 8th St., Sept. 13, 1909.

The amount of current necessary to start electrolytic action on iron and steel in particular cases has been a matter of considerable study and difference of opinion among investigators. Prof. Jackson of the University of Wisconsin, after extensive experiments upon iron electrodes in clear sand and a solution of nitrate of soda, reached the conclusion that to start electrolysis there is necessary "a mere directive force". The amount

of metal lost under exact conditions can be calculated theoretically from the electro-chemical equivalent of the metal in question, according to Prof. A. F. Ganz amounting in one year with one ampere of current to twenty pounds for iron and seventy-four pounds for lead. Because of polarization and the varying passivity of metals these maxima are far in excess of any known losses, tests by Herrick showing that only three and one-half percent of the theoretical loss is attained. In Pittsburgh under potential differences not exceeding a fraction of a volt no deterioration of water pipes has been detected.

METHODS OF MITIGATION

Six more or less prominent methods of electrolysis mitigation have been advanced:

First: An underground street railway system, commonly known as the double trolley system.

Second: The return pipe feeder system.

Third: Substitution of alternating for direct currents.

Fourth: Insulating joints of pipe lines.

Fifth: Coating all underground structures with a non-ionizable coating.

Sixth: The bonding of all rails as return feeders.

The double trolley system is not a scheme of electrolysis mitigation but a scheme of electrolysis prevention. Without doubt no electrolysis of underground structures can be chargeable to the currents of this system, and in the cities of Havana, Cincinnati, and portions of New York and Washington, where the double trolley system is in use there is no electrolysis of underground structures. In general the double trolley system should be adopted; if, however, the cost of installation of such a system is prohibitive some less expensive method of remedying the evil must be undertaken and the return pipe feeder system appears to be the only other logical solution where there is an extensive street railway system.

The objections to the return pipe feeder system are: That the system is never completed in that changes must constantly be made to provide for the changes of loading, car routing, and pipe distribution; that the car service, the gas, the water, the

telephone and telegraph services are generally supplied by different agents so that the responsibility for the installation and the maintenance of the system rests with several parties; that the limit of the pipes as carriers of return electric current, in the vicinity of the power stations, will be reached far in advance of the limit of the extension of the power of the power stations; that the installation of sufficient copper return feeders from the pipes to the power stations to render the pipes of the entire territory negative at all times would be of almost prohibitive expense.

Regarding the electrolytic effect of alternating currents laboratory tests using high frequencies show rapid corroding action, but under commercial conditions Mr. J. L. Hayden concludes the resulting effect from alternating currents rarely exceeds one-half of that from direct currents. Other investigators, however, claim that the effect is even more serious under the alternating current system. Mr. A. P. Trotter has found electrolysis to occur upon submitting buried lead pipes to an alternating current of a density as small as one-fortieth ampere per square inch. Experiments by A. Larson upon the effect of reversing the polarity of direct current indicates that by hourly reversals electrolysis is reduced to one-thirtieth part; but judging from the conflicting opinions on the whole subject of alternating currents it seems hardly probable that relief will be found in this direction.

Insulating every joint or every few joints of a cast iron pipe line would, without doubt, render the pipe line of such high resistance that little, if any, return current would travel in a longitudinal direction, but would in no way prevent returning earth currents from passing from one side of the pipe to the other causing an electrolysis of the pipe at the point or points where the currents leave the pipe for the earth. There are many cases on record where pipes have failed from the action of earth currents, these failures generally occurring in damp ground or along the courses of underground streams.

There are paints which are practically non-ionizable and such paints do prevent electrolysis where the underground

structures are entirely coated provided that such coating remains intact during the construction and repair of that structure and other adjacent structures; a condition that is practically impossible in our city streets. The coating of structures with cement and similar material must be discarded because of the incident expense except in rare cases.

The rails of the street railways system in Pittsburgh were, in 1905 and 1906, usually well bonded; the method in use being the electric weld. However, a large amperage of current did shunt to the earth from the rails; this inasmuch as the rails were overloaded. Even in cases of small railway systems where the rails, as return feeders, are not overloaded, the rails will shunt to the earth, particularly where the ground is saturated, sufficient current to damage underground structures.

In conclusion, the only certain method of preventing electrolysis is the installation of the double trolley system and the most successful method of mitigating electrolysis is the installation of the return pipe feeder system.

DISCUSSION

Mr. Burton McCollum:* I have been very much interested indeed in the paper. It speaks of a subject in which I have been interested for a considerable time and is very closely allied to the work we are doing at the present time in the Bureau of Standards.

The paper is especially interesting because of the light which it throws on a long drawnout controversy as to the advisability of tying any pipe system to the negative bus-bar in the power house. For many years a good many engineers strenuously opposed that system, and others very ardently advocated it. The observations Mr. Lanpher has given us seem to make out a very good case for the system used here under the conditions that prevail in Pittsburgh. Of course the objection that is urged by a great many is that there is a tendency for the current to be shunted around joints, the joints having a relatively high resistance in relation to the pipe itself, and any ten-

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dency which would increase the amount of current in the pipe would naturally increase the amount of corrosion at the joint. It is evident that the amount of current that would be shunted around a joint is a factor of the conductivity of the soil, and that I think is a matter that is at the bottom of the controversy. Some soils are of very much higher resistance than others, and consequently in such soils there would be only a slight tendency for current to be shunted around the joint; on the other hand with soils of very high conductivity there would be a greater tendency for the current to shunt off and consequently more danger of electrolysis. It can not be questioned that there are cases in which joint electrolysis has occurred. I have seen pipe lines in which, when uncovered, one could tell at a glance which was the positive direction along the pipe line and which was the negative direction, simply because one side of the joints was uniformly corroded and pitted and the other side was protected being negative. I think I have never seen any data on the subject of the resistance of soils in Pittsburgh and the results of Mr. Lanpher's four years of observation are essentially interesting.

I was interested in the relation of joint resistance to the resistance in the pipe itself. I have recently taken some measurements of cast iron pipe with lead joints and we found very wide variation. The resistance of a single joint may vary from ten times the resistance of a five foot length of pipe to forty, or sixty times that resistance. This shows that practically all the resistance of a cast iron pipe is in the joints and it is the joint resistance that determines the flow of current which we get with a given difference of potential. That seems to indicate that unless the soil resistance is rather high we should keep close watch for joint electrolysis. The greatest uncertainty comes from the fact that the joint resistance itself is not constant. If it were we could measure it in the beginning and be comparatively safe. But it is certain that it does change greatly and we may have a particularly low resistance today, one which will not produce a serious condition, but in five years from now, due perhaps to corrosion of the joints, or to mechanical causes,

the resistance becomes higher. There is always this possibility that a high resistance may develop in some of the joints and for that reason it would seem to me wise where this system is installed to keep close watch on the pipe joints.

The method just the opposite of this, the insulated joint, has been referred to briefly. It must be admitted that that is a method to be considered rather in the installation of a new system. It can hardly be proposed seriously in cases such as you have in Pittsburgh. It would mean practically relaying of the entire pipe system.

There is one point I want to bring out in this connection, the possibility of electrolysis of the steel structure of buildings, especially footings. It is pretty certain that the steel structure of buildings is going to be at practically the same potential as the water pipes, etc., that enter them. If the pipe system is strongly positive to the earth that would mean that the footings of the steel structure are also positive to the earth and will be discharging currents into the system the same as the pipes, and there is therefore a possibility of corrosion of the footings and possibly other parts of the building. Anything that will tend to keep down the difference in potential between the pipe system and the earth will obviously reduce the potential of the steel footings and consequently reduce the danger to the building.

And bearing on that point I might mention that some years ago before this system of negative return feeders was installed, observations were taken on the Pennsylvania train shed and it was found that in some places the footings in the train shed were as high as nine volts positive to the rails. It was quite evident that there was the possibility there of corrosion of the train shed footings. A few days ago, after this system had been put in these readings were repeated and it was found that instead of being nine volts positive to the rails they varied from one volt positive to one or 1½ volts negative, indicating a neutral condition which was not indicative of any danger at all.

Another point the speaker referred to is the question of insulating coatings on pipe lines. I have not had very much experience in that line, but we are carrying out a rather exten-

sive series of experiments along that line at the Bureau of Standards and we have obtained a few facts. An insulating coating is a good deal more apt to break down if it is on a pipe which is positive than if put on a pipe that is practically neutral. The reason seems to be that almost none of those coatings are absolutely impervious. A slight trace of moisture will get through even if the coating was originally in good condition, and when a little moisture does get through, a weak current will flow through which will result in a very feeble electrolysis and the generating of gas and as soon as the gas begins to generate the increase in volume causes expansion, and the coating finally becomes simply a mass of bubbles and degenerates very rapidly. I am not prepared to say just how much shorter the life will be where there is electric stress on the coating, but as the stresses are considerable, as much as 10 or 15 volts, it may be enough to break the coating down within a few months.

There is one danger in connection with insulating with coatings, viz: That if the coating does break down in that way it is apt to aggravate the danger of electrolysis rather than minimize it, because where the insulating coating is intact the current can not flow off and if it breaks down locally the flow of current is concentrated at a few points and that will result in local pitting which will destroy the pipe much faster than if it flowed more uniformly.

The speaker brought up the question of alternating current electrolysis and quoted some figures in regard to the comparative corrosion between alternating current electrolysis and direct current electrolysis. I think those figures require some qualification. Mr. Lanpher quoted some figures showing that the corrosion in the case of direct current was not more than 3½ per cent of the theoretical maximum. That is a matter which depends altogether on conditions. If the corrosion takes place in a very strongly alkaline medium you may expect an even smaller percentage than that. In some cases I have found that there was absolutely no appreciable corrosion in a strongly alkaline medium. If you make it slightly acid, corrosion will in general be very much greater. I think in almost all soils we would ex-

pect corrosion under direct current to be much greater than 3½ per cent of the theoretical maximum.

As to the possible protection of pipe by cement, it is probable that a cement coating on a pipe will increase the resistance between the pipe and the earth and will to some extent reduce the amount of current which will discharge from the pipe into the earth. But when cements are wet they are by no means insulators and the current will go from the pipe through the cement. And when the current does flow off it corrodes the iron more or less and produces products of corrosion occupying a larger volume than the original iron and the result is a swelling which may ultimately crack the cement so that whatever protection the cement might have given in the beginning, would in time disappear because of the destruction of the coating.

I would like to ask Mr. Lanpher if he has any data available on the resistance of soils around Pittsburgh?

THE AUTHOR: The resistance of the earth as measured in 1905 between the pipes and rails varied greatly, and considering the city as a whole the average resistanc was high.

In the Point section from Third to Twelfth St. and Grant St. the resistance varied from 0.012 ohms to 0.05 ohms, averaging about 0.02 ohms.

In the low section along the Allegheny River to Thirty-fourth St. the resistance varied from 0.009 ohms to 0.04 ohms. In the low section along the Monongahela River the resistance was slightly higher than in the Allegheny River section. In the higher section of the city the resistance averaged about 0.05 ohms, and in many sections where the ground was dry the resistances were 0.08 ohms and above.

MR. J. O. HANDY*: Analysis of the water supply coming from 80 to 100 ft. depth shows only a very small amount of alkali salts. Carbonates of lime and magnesia predominate. The soil would show comparatively high resistance.

*Chief Chemist, Pittsburgh Testing Laboratory, Pittsburgh.

MR. F. UHLENHAUT, JR.*: It is rather dangerous for a public service man to talk on electrolysis. The question itself is interesting. The only question is the treatment. Mr. Lanpher seems to believe that the only thing to do was to ask the present service company to do it and they will do it. They will do it if they now what to do. The city employed E. E. Brownell, who bears the title of consulting engineer, to tell them what to do. And when he had told them what to do they promptly shirked the responsibility. We wanted a decision as to the proper method to follow, whether to bond the pipes or put in insulated joints of negative boosters, or what to do. We finally accepted the report of the city's expert and bonded the pipes and I believe the results we got are satisfactory.

Of course, you understand in Pittsburgh geographical location of the whole city practically forces all the current generated from one current source, Herron Hill, into a concentrated area and it is very natural to have the greatest electrolytic effect at the point nearest the power station building where the current leaves the pipe. But despite this fact, when the pipe actually broke it did not break at Twentieth or at Twenty-first St., but it broke practically in an immune area down at Twelfth St. It is fortunate for us that it did, for if it had broken at Twentieth St. you see where we would have been.

There are a few other statements in this paper that in view of the fact that this is a scientific body ought to get on the record correctly. Mr. Lanpher states that something like 2300 to 2800 amperes of current flowed through the pipes before this mitigation work. I do not know how he got the figures, but I presume he got them from Mr. Brownell, and I will tell you how he got them. Those of you familiar with electric equations know that the current is equal to the electro-motive force divided by the resistance. He had a volt meter and an ohm meter and he would take the readings at a specified point and from them he would get the current. And then he would take them at a certain number of other points from which he would get the

*Chief Engineer, Pittsburgh Railways Company, Pittsburgh.

current flow. I said to him, "If you get ten times the number of readings you would get ten times the current, wouldn't you?"

I do not know that there is anything more to be said on this excepting that we want you to feel that electrolysis is not the element of danger that everybody seems to think. When Mr. Brownell was in this town he got into the newspapers, so much so that the Pennsylvania Railroad Company thought that the Union Station was no longer safe to inhabit. The station is still standing and we are taking readings and the city is taking readings and as long as the conditions are as they are there is no danger to be anticipated.

In regard to joint trouble, while I have not seen a large number of joints in water pipe, those I have seen were very nearly immune, and those that were affected were affected around the bowl of the pipe. In Philadelphia, where, due to ordinance conditions, all the trolley feeders were placed under ground, we had practically no electrolysis in the lead cables supplying the power for the trolley system. All of those cables were directly adjacent to the tracks so that any power from the lead sheet of the cable to the tracks would cause electrolysis quicker at that point than at any other and they took up some of the wires last year and neither the water pipes nor the cables of the trolley system were in any measure affected. There would be no joint trouble there because the joint in the cable would naturally be avoided.

Mr. F. N. Speller*: I do not believe I have very much to add to what has been said. The speaker touched on the effect of local electrolysis. To correct a misapprehension that is very widespread as to corrosion being often due to irregularity in the composition, I might say that we made a great many experiments along that line which indicated that steel or iron has to be much below the average before the irregularity incident to commercial material became an important influence in corrosion. As a matter of fact, the difference in potential between the greatest irregularity which you ordinarily find due

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to segregation does not begin to compare with the differences due to the accidental presence of foreign material such as mill scale on the surface of the metal itself. If you could remove all the scale from the pipe you would probably have much less trouble with the corrosion of underground piping.

Talking about conductivity in joints, I might add that we had occasion to measure the resistance of threaded joints at one time on two-inch pipe. It appeared that the resistance of the joint was practically the same as the resistance of a corresponding piece of pipe.

PROF. W. E. MOTT*: I do not think I can add anything from my own experience, but as I listened to the paper I was wondering if Mr. Lanpher could tell us anything regarding studies of pipe lines which have been jointed with wooden wedges. Have such studies been made?

THE AUTHOR: I have had no personal experience with the insertion of wooden wedges; however, the general effect of the insertion of wooden wedges has been to cause the current to shunt around such joints where the wedges were dry, and with practically no effect where the wedges were wet. I know of no case where a sufficient number of such wedges have been installed to prevent current from passing longitudinally along the pipe lines.

MR. BURTON MCCOLLUM: There has come to my knowledge through correspondence several cases in which wooden sections have been inserted in pipe lines with the idea of breaking up the continuity of the pipe line system, and the reports that have come to us in these letters have invariably been that they have had no trouble with electrolysis around the joints. But I have not had opportunity to examine any of those cases personally to know how satisfactory they have been.

MR. J. O. HANDY: I would like to ask Mr. McCollum if he is familiar with what is being done in foreign countries to meet the same conditions so far as they exist there.

*Professor of Civil Engineering, Carnegie Technical Schools, Pittsburgh.

Mr. Burton McCollum: I think the tendency in foreign countries is to place the burden on the public service corporations even more severely than it is placed in this country. Noticeably in Germany and Great Britain, where they have proposed and in some cases enacted legislation limiting the difference in potential that may occur between different parts of the system and the power house. In this country it is a grave question as to how far you can carry that matter of limiting the difference in potential. In Great Britain I think they limit it to 7½ volts between any part of the system and the power house negative. That would be considered very severe in this country. In Germany they have proposed to have even smaller difference of potential between different parts of the system and the power house.

I am not yet satisfied in my own mind as to whether or not it is wise or just to have any such voltage limitation, or if it is, just what that limitation ought to be. That is a subject we are studying at the present time. I am inclined to think that the tendency in this country also is to place a little too much of the burden of preventing electrolysis on the public service corporations.

It seems to me that we ought to recognize that the street car companies are like the water companies, public service corporations, and while it is their duty to do all they can in preventing large differences of potential, I think it is not unreasonable to ask that the other parties interested should co-operate in every way practicable in mitigating the trouble.

Mr. J. O. Handy: As to the method of keeping down difference of potential in foreign countries, do they use similar bonding methods?

Mr. Burton McCollum: They use plenty of copper in the return system. The most interesting phase is the proper distribution of the material in the negative return circuit. In order to keep the difference of potential down to a minimum with the minimum of conductor in the return circuit, that conductor should not all be tied into the rails at one point. The best way

is to install a number of negative return feeders runnng from the power house to different points in the system. If negative return feeders are run, insulated from the power house negative to various points of the system, and if the resistance of these feeders is properly proportioned, it is possible to keep the difference of potential between different parts of the system very much lower with a given amount of copper than if that copper were simply put in parallel with the rail return. A booster system is sometimes used in connection with the return feeders and results in still further reductions in the potential gradients in the earth. If proper precautions are taken with that system I think the difference in potential can be kept down to within sufficiently small limits so that you will have little trouble with electrolysis; and if in connection with this, insulating joints are properly installed in the water pipes the trouble should disappear altogether.

This is a case requiring co-operation, of course, between the railroad company and the water company and that is the best solution to my mind where you are building new lines extensively. Where you have a large system already in place it is very different.

Mr. J. P. Fox: I have spent a great deal of time on railways companies in Europe and I have never heard a complaint of the cost of guarding against electrolysis. The city of Berlin furnishes all the power for lighting as well as street railways. The chief engineer told me that they had never known a single case of electrolysis anywhere in the city. That was avoided by having negative return feeders at all feeding points in the system. The feeders are all in duplicate to every point.

In England I think they use the same system. Of course, that means great expense, but in foreign countries they are so used to using precautions of that sort that they do not complain or think it an imposition. In England they use boosters on their power houses universally to prevent the excessive differences of potential, also they use the fourth rail quite much. They do not depend on their running rails for their return current, but

install a fourth rail, and I believe those rails are outside. They of course are thoroughly bonded and protect the runways absolutely.

A MEMBER: Is there a voltage limit rule in vogue in Berlin?

MR. J. P. FOX: I have forgotten. I will have to look that up.

MR. BURTON MCCOLLUM: I do not believe there is a definite limit in Germany at the present time. It has been proposed to limit the different of potential to two volts. I do not know how seriously that is taken, but it would seem to be out of question unless they go to inordinate expense in installing a booster system in connection with the negative return feeder.

MR. W. EDGAR REED*: In alternating current electrolysis the corrosion seems to depend on the frequency. The corrosion with 25 cycle currents being considerably greater than for 60 cycles. The effects of alternating currents from laboratory tests seem to be only a few per cent of those of direct currents. With alternating currents the positive and negative sections reverse their polarity with every reversal of the current, and it is, therefore, impossible to prevent all trouble by bonding. The connection of aluminum cells between pipes and negative bus-bars has been proposed to remedy this difficulty. The cells allow the current to pass in one direction only, their action being similar to a check valve.

The corrosion of lead is generally considerably greater than iron. Lead pipes and lead covered cables require more attention than iron pipes, but all steel buildings and underground metallic structures must be properly protected in presence of stray currents.

It is quite interesting to know that there has been practically no erosion or electrolytic effects upon the Pittsburgh water piping for four years, although it is difficult to keep the pipes slightly negative to ground at all hours of the day under the varying conductivity of the soil. To be certain of proper voltage

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conditions requires eternal vigilance. Bonding does not prevent destruction by currents that cross pipe lines.

Bonding with metallic conductors from pipes to power house seems to have been very effective in Pittsburgh, where the dangerous zone was small, and I should like to know whether bonding was limited to the danger zone of the 1905 survey.

THE AUTHOR: The bonding is entirely inside of the former positive or dangerous zones.

MR. W. EDGAR REED: Are all the pipes lead caulked?

THE AUTHOR: All cast iron pipes in Pittsburgh are lead caulked except in a few negligible cases where universal pipe has been used.

MR. W. EDGAR REED: Electrolitic corrosion can be reduced by increasing the resistance of pipe lines so that a small current passes over them or by decreasing the resistance between pipes in the positive district and the power house so that a large part of the current in the pipe line will leave it through metallic conductors instead of the earth. This requires that all piping should be slghtly negative to the ground. The object of the British Board of Trade Rules is to limit the drop of voltage between all rails and power house and also the current returning through the ground so that little or no damage is done underground structures. The voltage limit fixed by this Board is 7 volts and the current limit is 5 per cent of the current output of the station. This means that larger return feeders are required than is the general American practice where several times this drop is frequently found. The rules also require daily records of various important conditions of street railway systems.

Mr. McCollum has stated that insulated pipe joints are sometimes to be recommended. This means increase of resistance to the flow of currents along the line and if much current passes there will be electrolysis at the end of each pipe section where the current leaves the pipe to enter the ground in its path around the insulated joint to the next pipe section. The resistance must in this system be great enough to reduce the current

to a very small amount or more electrolytic destruction may occur than with the bonded joints. Steel riveted, wrought iron screwed and cast iron lead jointed pipes have low resistances compared with cast iron cemented or insulated pipe joints and iron sheathed cement pipe which are used with the high resistance method. The conductivity of the soil varies with the moisture and nature of the salts present. In the order of their activity the earth salts are generally given as chlorides, nitrates and sulphates.

I should like to know under what circumstances Mr. McCollum recommends insulated pipe joints.

Mr. Burton McCollum: If you are going to install insulated pipe joints there is one thing absolutely essential, and that is to keep the negative feeders off the pipe. If you are going to tie your pipe line to the power house negative, then your insulating joint put in the pipe will be a detriment rather than a benefit. But if you keep the negative feeders off the pipe entirely and then break up the continuity of the pipe system by means of insulating joints, it is possible to keep the return flow in the pipe so small that its effect is almost absolutely negligible. We have shown by experiments at the Bureau of Standards that it is possible by the use of insulating joints to reduce the currents in the pipes to a negligible amount.

Now this system of insulating joints has been tried in a number of places and in some cases has been abandoned as impracticable. It is my opinion that in those cases where it has been abandoned, the results have not been satisfactory because not enough insulating joints have been used. A common practice in some cases has been to put in an insulating joint about every 500 ft. That is not enough. That length of pipe will pick up a considerable amount of current under favorable conditions, and when this current comes to an insulating joint it must flow around it and the current would be enough to destroy the pipe there in a short time. If you had an insulating joint every ten ft. instead of 500 ft. you would reduce the current it could pick

up to so small an amount that it could not do any appreciable damage.

One other point in connection with what Mr. Lanpher brought up is of interest to me. That is the question of electrolysis due to transverse currents in case you have the insulating joints in the pipe. I must admit that there are certain very special conditions under which there will be some electrolysis due to these transverse currents. But a little consideration will show that those are exceptional cases where you have this system of insulating joints installed. In an ordinary locality a pretty high potential gradient in the system would be 20 volts to the mile. This would give only about 0.004 volt per ft. and when we consider the high resistance of even wet earths it is evident that the current density in the earth would be so small that a pipe placed at right angles to the direction of flow could not pck up enough current to cause appreciable damage.

On the other hand, if you have a large pipe system such as a gas system that does not have insulated joints, extending over a large area and picking up large currents, and some part of that system comes very close to the water system, all the accumulated current of a large area may flow in a transverse direction across the water pipe and there you would have a very high potential gradient localized, and might have trouble from transverse electrolysis. Where such trouble is local a large pipe laid outside, not connected with the pipe system, would serve as a very effective shield.

J. P. Fox: What effect does a concrete foundation under the rails have on reducing the flow from the rails? In England and on the Continent practically all the rails are laid on a concrete base extending over the entire street. The rails are almost never in contact with the earth in any way. What effect would that have on reducing the flow of current over the rails to the earth?

Mr. Burton McCollum: Under those conditions I am quite sure that the rails would be in some measure insulated from the earth. It is simply a question of the relative resistance of con-

crete and earth. A number of experiments have published data on that subject. Some have reached the conclusion that wet concrete has about the same resistance as the earth. But with the moisture content that would ordinarily occur at points near the surface I believe concrete would have somewhat higher resistance than the earth and there would be somewhat less tendency for current to flow. That would depend on the resistance of the earth altogether. There are some earths that have higher resistance than concrete. I know of one case where rails were laid on an ordinary street, not on concrete at all, there being a straight length of line of about seven or eight miles of double track, and a careful survey indicated that there was very little leakage from the rails. That was a locality in which the soil resistance was quite high.

Mr. L. P. Blum: Is this question of soil conductivity altogether a matter of moisture content of the soil, or is it in any way due to other causes?

Mr. Burton McCollum: In answering that I would say that the conductivity of the soil is a function both of its composition and moisture content. It is probably affected more by the moisture content than any other one element, but samples of soils from various localities of the same moisture content, will vary very widely in specific resistance, depending on the composition of the soil.

Mr. L. P. Blum: In general is steel or cast iron pipe most affected by electrolysis?

The Author: In Pittsburgh the electrolysis pits were in general deeper in cast iron pipe. This is probably accounted for by the fact that the cast iron pipes were in general older than the steel pipes. In general the most aggravated cases of electrolytic action were found at the steam railway crossings where the rail bondings have been broken, causing the current to shunt from the rails to the pipes, returning again to the rails on the opposite side of the crossings.

CORRESPONDENCE

Mr. L. B. Smith*: Local electrolysis has been spoken of and Fig. 8 is offered as a striking example of corrosion due to this cause. The 60-in. Allegheny steel main in question runs for several blocks in Sharpsburg on a street largely of cinder and clinker fill, and in two places surface leaks have made manifest serious pitting. Temporary repairs were effected by inserting corporation cocks in the deepest pits; also by a specially designed plug inserted with a tapping machine. By sawing off the plugs flush with the pipe they could be placed quite close which in some cases was necessary. Protection from further deterioration is contemplated by means of a layer of clay or concrete around the pipe.

During the last four years, since mitigation work in Pittsburgh was first inaugurated, voltmeter surveys have been made yearly in order to keep record of varying conditions and to be able to check at an early stage any increase in area or intensity of the so-called "dangerous districts."

In carrying out this work a city driller's wagon provided with a rear step is used. The corps consists of two men for making contacts to the rail and fire hydrant, one instrumentman who notes and records readings of potential and a fourth who does the driving. The instrument reads on the upper scale to twenty-five volts with half volt divisions and on the lower scale to five volts by tenths and has a zero-center so that no time is lost due to unexpected direction of current flow or in obtaining readings which fluctuate from positive to negative. By this method all streets having car service are traversed in about ten days.

Following is a summary showing the extent and character of the last complete survey taken in July, 1910:

District	Central Pittsburgh	North Side	South Side	Total for City
Total No. of readings.....	490	338	132	960
No. of readings negative	458	260	86	804

*Assistant Engineer, Bureau of Water, Pittsburgh.

No. of readings positive or fluctuating from + to —....	32	78	46	156
Ditto. above 0.5 volts positive....	21	11	12	44
Ditto. above 1.0 volts positive...	6	3	3	12
Maximum positive reading, volts....	1.4	1.3	1.55	1.55

These results are typical of conditions during the summer surveys and indicate that very few danger districts now exist. All districts, however, where positive potential have been found are again checked at six months' intervals; and it is usually found that the winter readings are somewhat lower, as is to be expected.

A feature of particular interest lies in the disclosures of a special survey of June 28th, 1909. It will be remembered that on this date no cars except United States mail-cars were in operation, a universal strike having been declared on the previous day. In the one day two city corps covered practically all districts which are normally "danger zones" and noted electrolytic conditions differing widely from anything observed before or since, i. e.:

(a) The major part of districts ordinarily positive were on this date slightly negative.

(b) No positive reading greater than 0.15 volts was discovered except where observation was taken while a mail-car was in the vicinity.

(c) Wherever positive readings existed the potential was materially reduced so that in many cases a milli-voltmeter was required in order to detect the reading.

The data thus offered furnishes unusual evidence of the prime source of the electrolytic trouble in this city and would indicate that with no street cars in service, the districts of positive potential on the water mains would entirely disappear.

Mr. Morris Knowles: In connection with the history of electrolytic troubles and their solution in Pittsburgh, which has been so admirably described by the authors of this interesting paper, a brief outline of the methods used to protect the steel main, from Highland Reservoir No. 2 to the South Side, may be of interest. This line was designed and constructed under the supervision of the Bureau of Filtration, in connection with

the building of the filtration works at Aspinwall. Its purpose was to convey filtered water to the South Side territory and to reinforce the distributing system at various points between the Allegheny and the Monongahela Rivers.

The main is of riveted steel pipe of the usual design. The diameter of the line from Highland Reservoir to the bank of the Monongahela River, a distance of about 26 000 feet, is 50 in., while the river crossing and the portion on the South Side, a distance of about 4000 fet., is 36 in. The route of the pipe is as follows, from the outlet gate house of Highland Reservoir No. 2 to Negley Ave. to Baum, to Graham, to Ellsworth, to Clyde and then along Boundary St. and the B. & O. R. R. right of way, new Boundary Street and Greenfield Ave., as far as Second Ave. Here the line reduces from 50 to 36 in. and continues through the property of the Jones & Laughlin Steel Company, across the river and along South 34th and East Carson St., to just beyond South 30th St., or more exactly to Water Works Alley, where connection is made to the distribution system.

The protection work undertaken, consisted of bonding the pipe at all lead joints, so as to provide a path of low resistance around the joint; and thus prevent the current from passing from the pipe to the ground, which would result in electrolytic action at the point of departure. The problem of bonding a steel main is simpler than that of a cast iron pipe, because the ordinary joints in the former are riveted and there is practically no change in conductivity of the line except at special joints. These joints, which occur at valves, are usually made with lead. The method employed to prevent electrolysis in this case consisted simply of carrying a copper cable over the lead joints adjacent to the valve, in order to control the path of the current and prevent its escape into the earth.

About six feet either side of the valve, a copper plug 6 by 6 by ½ in. is fastened to the steel plate by four ½ in. rivets. Particular attention was taken to have the surfaces of the pipe and of the plug thoroughly polished and free from any dirt, so as

to insure a good contact. Each plug is provided with a post two inches high and one inch outside diameter. In the middle of this post was a ½ in. hole into which the end of the cable was soldered. From each of these plugs, a copper cable of 500 000 cir. mils. capacity, extended to a plug placed on the side of a brick chamber, built around the end of the valve.

The total length of cable between the plugs on the pipe is 42 ft. The portion of cable inside the chamber is flexible insulated copper and the portion outside which is laid in the ground, is further protected by a lead covering. The ends of the cable in the chamber are soldered to brass terminals $4\frac{7}{16}$ in. long, with an outside diameter of ⅞ in. at one end and $\frac{7}{32}$ in. at the other. The circuit is completed by inserting the terminals in two binding posts, which are part of the plug. Thumb screws are used to hold the terminals in place securely.

The object of this arrangement was to afford opportunity to measure the current, by simply removing the terminals from the plug and connecting in the proper instruments. Gauging stations were also placed on the pipe line at certain other points where chambers were available, such as at air valves and at man-holes. The details of the bonding of the cables to the steel main were identical with those used at the line valves and the cable ends inside the chamber are soldered to the terminals ready to insert in the posts of the testing apparatus.

The above work, decided upon as a result of Mr. Brownell's report, was done for the city as a part of the regular contract, and was completed during the discussion between the railway company and the city, but prior to the beginning of the mitigation work described in the paper. The only connection made between this main and the power house, at 30th and Carson Sts., on the South Side, has been fully described and illustrated in the paper. As yet no readings have been taken at the gaging stations described.

Prof. A. F. Ganz*: The paper is evidently written for the purpose of presenting to water works engineers a method of pro-

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tecting underground piping systems from electrolysis, which according to the paper has been found satisfactory during four years' experience in Pittsburgh.

The present installation is based upon an electrolysis report and recommendations made by E. E. Brownell to the City of Pittsburgh in 1905. This report recommended, as stated in the paper, first, bonding the water pipes at various places to the negative bus-bar of the power houses with heavy copper cables, and second, bonding around the calked pipe joints with heavy copper cables principally in the positive areas.

It is stated in the paper that the water pipes before being bonded were found to have a maximum potential of 24 volts in the positive district. As the maximum negative potential is almost always greater than the maximum positive potential, and as the drop in the rails is equal to the sum of the positive and negative potentials plus the drop in the pipes, it follows that the maximum drop in the rails must be over 50 volts and is probably much greater. With such abnormally high potential differences it is no wonder that very serious deterioration was experienced. It is also no wonder that it required 17 one million circular mil cables to drain the current from the water pipes to the negative bus-bar at one power station returning 5000 amperes from the pipes at this station alone, with a total station load of 12 000 amperes. It is stated in the paper that when these bond connections to the water pipes were made complaints from the gas and telephone companies were received to the effect that current was shunting to their pipes and cable sheaths and seriously endangering them. This is an inevitable result of bonding and one of the greatest objections to the bonding plan. It is stated that thereupon the gas pipes and telephone cable sheaths were also bonded to the negative bus-bars of the power stations draining current also from them.

Much of the electrical data given in the paper appear to be taken from the 1905 electrolysis report already referred to, and some of this is unfortunately wholly unreliable. For example, the paper states on page 239 that: "While it is true that the

amount of deterioration on an electrode is proportional to the amperage of a current rather than to the voltage drop, it is true that in the case the question the district of high positive potential so closely conformed with the district of high amperage of return currents that in the positive areas, the extent of deterioration conformed closely with the extent of the voltages." The method used for computing earth currents in this report is, however, wholly incorrect, as was well pointed out in an editorial severely criticising and in fact ridiculing this report, published in the *Engineering Record* for January 13, 1906, so that the above statements are also incorrect. The paper also states on page "This survey showed that about 480 amperes of current were brought into the 20th St. positive district by the water pipes, this in addition to about 2340 amperes of earth currents passing over the water pipes to the rails in vicinity of the power house," and also on page 247 the paper states: "It should be noticed that before mitigation work was started the amperage of the current leaving the pipes in this positive district was about 2800 while after the return pipe feeder system had been installed this amperage had increasd to about 5000." The values of earth currents given as 2340 and 2800 amperes in the above have also been calculated by the incorrect method and are not reliable. The fact probably is that the currents on the water pipes have increased from 480 amperes to 5000 amperes after the mitigating plan was installed.

In the paper it is stated that there are six more or less prominent methods for mitigating electrolysis. It is, however, not quite clear that the sixth method is a mitigating measure, as the bonding together of trolley rails is a necessary constructional feature of the track and not an electrolysis mitigating measure. It is certainly surprising that the authors do not even mention the one system which has universal recognition and which is the only one which has correct theoretical foundation, namely, the radial insulated return feeder system, which has been applied with considerable success in several Amrican cities and in a large number of European cities. In this system the return

feeders are designed to drain the rails of current at many selected points, leaving these points at the same potential, thus greatly reducing the rail drops and minimizing stray currents on underground structures. A recent installation of this kind is in Winnipeg, Can., where all bond connections to underground structures have been removed, and a radial system of insulated return feeders installed which drain the rails of current, so that now it is claimed that there are practically no stray currents on the underground pipes, as is well set forth in a report by Professor L. A. Herdt, in the *Canadian Engineer* for August 20, 1909.

It is quite obvious that the very acute conditions in Pittsburgh were due to wholly inadequate copper return feeders for bringing current back from the rails to the power stations so that the underground pipes are now made to return nearly 50 per cent of this current. It is also quite obvious that the first step which should have been taken was the installation of sufficient return feeders to the rails to bring down the rail drop and pipe potentials to at least reasonably low figures.

It is to be regretted that a system for preventing electrolysis should be put before the Engineer's Society in which nearly one-half of the current to one power station is returned by means of underground pipes. These enormous stray currents produce other great dangers and in their path through ground constitute an unmeasurable hazard to all other underground structures, including building and bridge foundations.

In my opinion the so-called mitigating installation in Pittsburgh is unqualifiedly wrong in principle and in practice. It does not even represent an intelligent application of bonding installed for the purpose of protecting the pipes from electrolysis, but appears to be installed rather for the purpose of utilizing the underground piping as return conductors for the electric railways, as would appear from the name applied to the plan, namely, "pipe return feeder system."

Whatever one's opinion may be it is apparent that the paper deals with things which have been done and on a scale

never before attempted. The final outcome cannot fail to be of the greatest interest and it is only to be hoped that the results may not be as disastrous as the present writer sees reason to fear. To him this paper, valuable as it may be as history, chiefly shows how far astray well intentioned engineers can be led by imperfect comprehension of fundamental but unchangeable electrical principles.

Mr. W. C. Hawley:* The paper presented by Messrs. Lanpher and Smith is exceedingly interesting and valuable for it deals with a method which has been proposed for the prevention of damage by electrolysis, but which has been generally disapproved. There has not yet been sufficient time for a test of its efficiency in this case and it must be remembered that because of the difficulties of making inspections of an underground pipe system, the actual results, either good or bad, may not become manifest for a considerable period of time. The reduction in area of the districts in which the water pipes were positive to the rails of the street railway system has been accomplished and the difference in potential largely reduced for existing conditions. However, these conditions are changing hourly and the quantity of current now returned through the pipes has been nearly doubled. Doubtless, damage at specific points has been prevented or largely reduced, but the material increase in the quantity of current returned makes it certain that a general deterioration of the underground pipe system is going on more or less rapidly and must continue to go on so long as the pipes are used as a return conduit for the electric current.

The damage to underground pipe systems by electric currents from street railways, etc., presents a very interesting question. It has been passed upon by the Courts in a few cases, as for instance, at Dayton, O.; Minneapolis, Minn. and Peoria, Ill., but in many cases, settlement has been made by the parties interested without the resort to legal proceedings. There can be no doubt of the general principle that the street railway company has no right to use the gas or water pipe system as

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a conduit by which to return a part of its current to the generator. This was clearly decided in the Dayton case and the Court would have ordered the double trolley system installed had it not been that the city had given to the trolley company by ordinance the right to use the single trolley system. The Court, however, imposed upon the trolley company the burden of preventing the escape of its current to the water pipes which were, in that case, owned by the city, or of paying for any damage by electroylsis which occurred to the pipes. In the Peoria case in which a decision was recently handed down by Judge Sanborn of the U. S. Circuit Court, the facts are briefly stated by the Court as follows:

"(1) The injury complained of exists.
(2) The injury is permanent and continuing.
(3) The injury has been and is being caused by the defendants.
(4) The complainant can do nothing to prevent the injury.
(5) The defendants can prevent it by the use of the overhead double trolley system which provides a completely insulated metallic circuit for the electric current.
(6) The overhead double trolley system, though more expensive to install, has been demonstrated by use and experience to be as safe, economical and satisfactory in its operation as the single trolley system."

The Court further found:

"It is possible for the defendants to so operate their railways by electric motive power as not to injure the complainant's property.

"It is impossible by any known method for the complainant to protect its property from such injury.

"Where there are two methods of accomplishing a legal result and one method will work an injury to another and the other will not, it is the duty of the person doing the thing to use that method which will not result in injury to such other person.

"The failure on the part of the defendants to observe such duty constitutes negligence, and when it results in damage to another, such damage is actionable.

"The injury found to be going on in this case is the direct consequence of the unnecessary and wrongful acts of the defendants in accomplising a legal result—that is, the propulsion of cars—and, unless the defendants are protected by their license from the city, they are liable to the complaint for such injury. These acts, unnecessary and

wrongful in themselves, are not rendered lawful by the ordinance granting the use of the streets for the purpose of propelling cars by electric motive power, and, inasmuch as they work 'hurt, inconvenience and damage' to the complainant, they constitute a nuisance which is actionable at the suit of the injured party.

"The injury complained of being actionable, there can be no doubt of the power of the Court to grant some remedy. The damage already done is chargeable to the defendants and, so far as such damage is capable of being definitely ascertained, the defendants should be held liable in a suit at law. But a suit and recovery at law would not stop the injury which is and must necessarily be continuous under existing conditions. The very life of complainant's plant and franchise is threatened. The only adequate remedy is therefore by injunction as prayed in the petition. The special master's conclusion is that the bill and evidence make a case of equitable jurisdiction, and that an injunction should be issued as prayed, subject to such reasonable conditions as to the court may seem right."

The Court's decision was as follows:

"Defendant should be enjoined from continuing the injury to the complainant's water mains and service pipes, and should be given a reasonable time to take such measures, or put in such improvements to its negative return as will substantially prevent injury. This should be upon condition that complainant co-operate with defendant so far as reasonable and proper in aiding it to prevent or lessen the escape of current from its rails, or in preventing the escape of current from the water pipes in such manner as to cause injury thereto. The matter of the terms of the decree in these respects, as well as the modification of the findings, will be further considered on application for decree."

The decision of the Peoria case is notable because of the immense amount of testimony which was taken and the long period of time covered by the court in investigating the matter. The case was brot in 1894 and the decision was handed down in 1910.

As above stated, the method adopted and described in the paper of Messrs. Lanpher & Smith for the prevention or mitigation of the damage due to the stray electric currents is not that which has been generally advised by those experts who have studied the problem of electroysis. Papers and discussions before the American and the New England Water Works Asso-

ciations for some ten years past have generally agreed that the only way to prevent damage to water and other pipes from electrolysis was to oblige those using electricity to provide a proper conduit for its return to the generator and thus prevent its leaving the street railway or other system and entering the pipe system as has been accomplished in Cincinnati, New York, Havana and Washington, by the use of what is known as the double trolley system. In the city of Washington, D. C., this system was adopted after careful investigation of its merits compared with the single trolley system, by Congress, which passed an act obliging the local trolley company to use the double trolley system. The installation of the double trolley system is expensive but it is believed that the economy due to its operation will more than off-set additional expense.

Those who have investigated the subject of electrolysis have been almost unanimously of the opinion that the only way to prevent damage to the underground structures is to prevent the electric current from leaving the trolley system. The expert employed by the City of Pittsburgh is on record in emphatic language as agreeing to this proposition. It seems strange, therefore, that he should have recommended to the city the method for mitigation which was adopted. In the Journal of the New England Water Works Association for June 1900, Vol. XIV, No. 4, will be found a paper on electrolysis by Mr. Brownell, in which not only the theory but the practical side of the question is thoroly discussed. The statement is made that damage to water and gas pipes is not confined to the districts where the pipe is positive to the rails but that it is going on constantly in the negative districts. The author of the paper shows that with the ordinary bonding of the rails the conductivity of the bonds is but a fraction of that of the rail and that with such bonding a considerable part of the return current is bound to leave the rails for the earth and any other path of less resistance which it can find. The paper is illustrated, showing the effects of various cases of electrolysis which are described. Mr. Brownell states:

"The main object should be to keep the pipes as much isolated from the rails and return circuits as possible. Under no consideration whatever should the pipes be metallically bonded to the rails or to the negative pole of the dynamo; for if this is done a larger portion of the current is induced to return by the pipe, as the total resistance by that route is thus decreased. Trouble will then result where the current passes from the pipe to the rail or from one pipe to another, and also from shunted circuits around each joint. * * * * * * * *

"The greatest objection to allowing any piping system to act as a return conductor, if it is negative to all other return conductors, is that electrolysis will take place at the joints. I have noted this action in the negative district in sixteen cities. In some cases the pittings were extensive, and reached to one half the thickness of the metal."

Subsequently the paper above referred to was revised and, with some additions, printed and distributed among those interested. The following are paragraphs from this revised paper (The capital letters appear in the paper as printed):

"Until recently it has been supposed that no pipes were in danger, except those which were electrically POSITIVE to, or of a higher electrical pressure than the rails of the electric railway. But recent investigations have shown that even in the NEGATIVE area serious electrolytic corrosion has occurred at the joints of cast-iron pipes, also upon the surface of contact between the lead calking and the pipe. * * * * * * * * * * * * * * * *

"To the municipal water works board, this problem must be solved to insure public safety and economy. To the city itself, it means the ruining of valuable street paving, by making the necessary repairs. To the water company, it is a matter not only of loss of property, but danger of the loss of franchise or of suits for damages on account of failure of the water supply during a fire. To the gas company, it means danger from gas explosions and heavy loss from leakages. To the insurance company, it means undue fire risks, largely increased by grounded circuits or by an insufficient supply of water to quench fires. To the citizen, it endangers comfort and safety. * * * * * * * * *

"It is my opinion that under no conditions whatever should the pipes and the rails be metallically bonded together; nor should the pipes form any part of the return conductors of an electric street railway, unless the leakage from the rails to the pipes is so trivial as to cause them practically no damage at the joints, which thus leaves this remedy very questionable.

"The main thing to be desired is to provide better return conductors than any piping line can offer, and not to seek the service of any line as a return conductor.

"When any piping line is metallically bonded, to the NEGATIVE side of the dynamo, the current is thus induced to return through it in inverse proportion to its resistance, as compared with that of the rails. Therefore if the bonding is poor or the slightest accident occurs to the many thousand bonds, the larger percent of the current will return upon these bonded pipes, while the conductivity of the piping line will practically remain the same for an indefinite period, but of course the rails are becoming more useless as return conductors, which in course of time, unless frequently reconstructed, will compel the pipes to carry the current, causing serious trouble from three different sources; shunted circuits around each joint (including screw joints upon wrought-iron pipes), alternating of the current from rails to water and gas pipes, and the alternating of the current from water pipes to gas pipes from which causes serious electrolytic action has developed even in the NEGATIVE areas, that were supposed to be safe.

"In the city of Indianapolis the water system is of the lowest polarity, caused by bonding them to the NEGATIVE side of the dynamo, which at the same time has the highest resistance of any of the return conductors. When remote from the power houses the water system is POSITIVE to the gas systems, and when within 3 000 to 5 000 feet from the power house the gas system becomes very POSITIVE to the water systems by reaching as high as 4.2 volts POSITIVE. This condition has causd *great* damage to gas and water (lead) systems over a great portion of this city, and which is not confined to those streets that are used by the Electric Street Railway. * * * * * * * *

"The greatest objection in allowing any piping system to act as a return conductor, even though that piping system is NEGATIVE to all other return conductors, is that serious electrolytic action will occur at the joints. I have noted this electrolytic action in some sixteen different cities in the NEGATIVE districts. In some places the cast-iron gas pipes were eaten entirely through at these joints, not a single piece of iron holding the pieces together. Upon many cast-iron water pipes the pittings extended nearly through the pipe. The current in these cases was large, as I have never noticed this action where the cast-iron pipes were carrying less than ten amperes. It should be remembered that the resistance of no two calked joints is alike. * *

"The fact of the case is this: that the electric roads have not, and it seems will not, invest the necessary CAPITAL to secure a practical result, and this they are morally and legally bound to do for the protection of valuable subterranean systems, as I think there is nothing too good for the betterment and PROTECTION of the public water supply, of which so much is expected. * * * * * * * * * *

"The proper time to call the electric street railway manager's attention to this important subject is before the damage is great. This

can best be done by employing an electrical engineer who is in every sense capable to do this important work, and he must be frank and HONEST, and not allow the influence of the local electric railway to induce him to recommend things that are petty and worthless. If he proposes merely to connect the water mains by a return wire, "to pump the current out of the water pipes," set him down as the wrong man and try another; it will pay you in the long run to do so, since he belongs on the aggressive side. * * * * * * * * * * * * * * *

"The usual manner is to connect the pipes with the negative busbar of the dynamo, which is the greatest SHAM and FAKE used to deceive the gas and water fraternity, and should never be allowed, as this false remedy is only misleading, by covering up the true and actual electrical condition of the pipes, which otherwise would have manifested itself.

"Serious electrolytic action will develop at the joints of any pipe line, whether POSITIVE, NEGATIVE or NEUTRAL, when that piping system is allowed to carry current of any capacity."

In view of the foregoing it would be interesting to know why Mr. Brownell recommended the adoption of the method described by the paper in the city of Pittsburgh. His paper published in 1900 is a complete answer to his report of 1905. There has been no change in the art in the intervening five years to warrant such a complete revolution of theory and practice and there has not been up to the present. The method of mitigation recommended in the report was suggested in the Peoria case but was not seriously considered. A "parallel column" comparison of the paper of 1900 and the report of 1905 would be interesting but would occupy more space than would be available to such a discussion. Had they been written by two different men there could scarcely have been more contradiction of statement and the conclusions are diametrically opposed to each other. The paper is clear, concise and emphatic. The report seems to be involved, labored, verbose, appologetic and confusing. The most interesting paragraphs in the report are the following from pages 69 and 70:

"Fourth: That the proposed plan is to extend from the negative busbar, in each respective power house, a suitable number of return negative copper cables are to be extended from the switchboard in the power house and connected to the water mains at such places or

points as shall thereafter be consecutively established, as to the locality, size of wire and the like.

"Interposed in the circuit shall be a large suitable main switch; so that at any time the switch may be opened and the normal electrical condition of the water pipes restored for any comparison. The entire plan of mitigation, or eradication, is invariably one of cut and fit, for there never can be any definite detailed plan outlined.

"Variables which constitute these electrical conditions are the entire basis of the work; that is, the resistances of the piping lines are not uniform, the drops over the rails are variables, and many other unstable electrical conditions.

"These can only be successfully and intelligently handled by dealing with the work consecutively, which requires considerable tact and skill, as each wire connection to the water system vastly alters the remaining electrical conditions of the water lines.

"The object is to eliminate the menacing currents from the water mains, permanently and harmlessly, at a reasonable cost." * * * * *

"Fifth: That calculating only from practical work of a similar character, which I have been carrying on successfully for several years, it is estimated that the total cost necessary for practically eradicating the evils of electrolytic corrosion upon the water piping system of the City of Pittsburgh will be about the sum of $35 000.

"By the use of this plan of mitigation, the value of the water mains to the Pittsburgh Railways Company would be equivalent, in copper, to not less than $225 000.

"THUS, SHOULD THIS PLAN OF MITIGATION BE INAUGURATED, THE PITTSBURGH RAILWAYS COMPANY WOULD EXPEND A SUM OF ABOUT $35 000 AND RECEIVE IN RETURN THE VALUE OF THE WATER SYSTEM AS A RETURN CONDUCTOR, BEING WORTH AT LEAST $225 000, AS STATED ABOVE."

There can be no doubt as to the value of this investment to the Pittsburgh Railways Company. What does the City of Pittsburgh get, however, in return for furnishing a return conductor worth at least $225 000? *First*: A reduction of the positive areas and a reduction of the differences of potential therein which reduces the immediate danger of damage by electroylsis in those areas. *Second*: The quantity of current returned by the pipe system instead of being reduced has been nearly doubled. *Third*: Conditions in the negative area have been made worse by the increase in current returned by the pipe

system. Unless the experience gained by the author of the report in sixteen cities up to 1900 goes for nothing, this condition is serious and must result in time in a more widespread destruction of the City's water pipes than would have occurred otherwise.

Mitigation is a poor substitute for prevention.

THE AUTHOR: In answer to several questions received it should be stated that the Pittsburgh mitigation work was carried out under the direction of Mr. Brownell and that I acted only as the "Inspector for the City" and was not responsible for the selection of the methods followed. However in 1905, I did recommend against the adoption of the system suggested by Mr. Brownell upon the following grounds: That the proposed system would not prevent all electrolysis but would change the boundaries of the dangerous areas; that the bonding of the pipe joints would necessitate cutting holes through the street surfaces at almost innumerable points; that the responsibility for the upkeep of the system would be so divided that there would arise constant differences with the street railways company, and therefore that the best course for the city to take was to insist on the installation of the ungrounded return system. These recommendations were made with little knowledge of the local conditions and they were not followed.

When it is considered that the legal proceedings necessary to force the installation of the ungrounded return systems in other cities have required from five to sixteen years to reach conclusion, and that such conclusion has not been reached in the State of Pennsylvania; also that the Pittsburgh water supply of the mill and business sections was so seriously threatened that the fire insurance underwriters were making investigations in view of raising insurance rates for these sections; also that the city released none of its rights in allowing the railways company to install the return pipe feeder system; also that the topography of the city is such few street car tracks are located in the vicinity of the power houses and there are no cross-town tracks leading to the vicinity of such power houses causing an installation of the so-called radial insulated return system to be

very expensive and impracticable; also that the railways company was not in a financial position, at that time, to make costly changes in its system. (See Report on the Pittsburgh Transportation Problem by Bion J. Arnold, 1910), and also that the results obtained have been satisfactory as described in the paper submitted. Therefore, the decision to allow the railways company to proceed to mitigate electrolysis practically as it saw fit and the decision of the railways company to install the return pipe feeder system appear to have been entirely warranted.

The paper attempted to emphasize the unusual conditions prevailing in Pittsburgh but it did not infer that under different conditions the results would have been equally satisfactory, in fact the conditions as they existed in Pittsburgh were almost ideal for the installation of the return pipe feeder system.

[NOTE: Additional discussion of the subject of Electrolysis, received before October 1st, will be published in the October issue of the Proceedings.—Editor.]

OPERATION OF BOILER PLANTS OF INDUSTRIAL WORKS

By John A. Hunter*

In the Pittsburgh District fuel has been so cheap that the economic operation of boilers has been given very little consideration. The great cry of the day, is conservation of our natural resources. The statisticians tell us that our deposits of coal will be exhausted within a comparatively short time, and they warn us that we must employ more scientific methods of mining and using coal, otherwise we shall rob posterity. Unfortunately, this is not a Utopian age and appeals of this kind do not have much influence on our financiers and managers of large industries. However, these men have recently been seeing their fuel bills increase and consequently are beginning to awaken to the importance of the economic use of fuel. It has been only a comparatively short time that we have regarded blast furnace gas as a valuable fuel. Even today we are just beginning to build by-product coke ovens to utilize the gases from the ovens. In the large steel plants the coke ovens and blast furnaces are located close enough to the rolling mills so that the only coal used at the plant is in the by-product coke ovens. In order to realize this desideratum it of course becomes essential that the boilers, if it is a steam plant, be operated at their best economy.

So now we find that the question of boiler efficiency is being given a great deal of attention and most of the large steel works have a special department which devotes all its time to this work.

In this paper I will endeavor to treat more particularly of the operation of a boiler plant and not of the design or construction.

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First the boiler plant should be established on the same operating basis as any other department. It should be considered as a producing department and should have its superintendent. This superintendent ought to be an engineer who thoroughly understands the operation of boilers and the theory of combustion.

Having established the boiler plant on the same basis as every other department in the works, it should be operated in harmony with all the other departments. If this is not done it can result in quite large losses, due to the blowing of the safety valves, etc. This condition can be avoided to a great extent by the superintendents of the other departments which operate steam using machinery. These men should notify the boiler superintendent of their operations and also of shut downs which can be anticipated, and in case of shut downs for accidents, etc., they should notify the boiler superintendent immediately of the probable length of time of the shut down. By this method the conditions in the boiler house can be arranged so that the load can be carried in the most economical manner.

If the boiler plant is to be considered as a producing department it must of necessity have its raw materials and finished product. The raw materials are fuel and water; the finished product, steam. This being the case, it becomes necessary to know accurately the amount of raw material consumed and the amount of finished product produced, also to know the condition and quality of each.

The first step then is to install apparatus to measure these quantities. If the fuel used is gas, a meter should be installed. There are many meters on the market which have proved very satisfactory for the measurement of natural and by-product coke oven gas. For the measurement of blast furnace gas there are now on the market several meters which give very accurate results. If the fuel is coal, its measurement is comparatively easy as it only requires the installation of a pair of scales, so placed that all the coal used can be weighed. There are several ways this can be done, the preferable way though, is to install the scales so that the coal is weighed between the storage bin

and the boilers. By placing the scales in this position, the exact amount of coal used at any time is known and it avoids the necessity of making an estimate of the coal in the storage bins whenever it is desired to know the amount consumed.

Until recently it has been practically impossible to get an accurate meter to measure the water. The displacement type of meter has never given satisfactory results. The Venturi meter has been used for this purpose for several years. It has been found sufficiently accurate for commercial purposes, and having no wearing parts its accuracy does not deteriorate. The Venturi meter should be installed between the feed water pumps and the boilers. This location is specified in order that all the water which enters the boilers will be measured, for if an open feed water heater is used the condensed steam must be included. It will also avoid any errors which might arise due to leakage at pumps or overflow from the feed water heater. The method of making these installations has been specified in detail, because it is absolutely essential to have correct records of the amount of fuel and water used, and in order to insure this, the apparatus for making the measurements must not only be of correct design, but must be properly installed. For it can readily be seen if these quantities are not accurately determined, one is handicapped and is to a certain extent working in the dark.

The writer does not consider it advisable to attempt to measure the amount of steam produced. If the amount of water used is known and suitable corrections are made for the amount blown down and wasted for emptying and filling boilers, the amount evaporated can be arrived at very accurately.

The next step after knowning the quantities of raw material used and resultant product is to know their quality. Considering first the fuel: if it is gas, the pressure at which it is measured should be known and its heating value should be determined at regular intervals. If the fuel is coal, its general character, the vein and mine from which it is taken should be noted. Samples should be taken and analysis and determination of its heating value made.

Taking next the feed water, a record should be kept of

the temperature at which it enters the boiler and analyses made at regular intervals to determine the incrusting solids, and also to determine if it contains any free or combined acid which might attack the metal in the boiler. Records of the steam pressure should be kept, also of the temperature if it is superheated. If it is saturated, calorimeter tests should be made to determine the perecentage of moisture.

In the operation of a boiler plant there is always a certain element of danger, for this reason the matter of safety should be given primary consideration. This can be done by regular and systematic inspection of the boilers both internally and externally. All parts should be examined and if any deterioration is found tests should be made to determine whether it is great enough to render the boiler unsafe. All safety appliances such as safety valves, water columns and their connections, steam gauges, etc., should be examined and tested at regular intervals.

To obtain the best economy the following conditions are generally recognized as essential, namely: the settings must be kept tight and free from air leaks, the baffles kept in good condition, the heating surface kept clean both externally and internally, the fuel burnt with as little excess air as possible, and if coal is used the combustible in the ash reduced to a minimum.

It is manifestly impossible for the superintendent to personally see that all the above conditions are maintained, so it becomes necessary for him to have a system of reports which will enable him to keep in touch with the actual conditions of operation. The following reports if properly kept will accomplish this:

Boiler Report: This should give the following data for each boiler: When washed; when thoroughly cleaned, i. e., the scale removed; when inspected; the condition of safety appliance; the repairs made; and the total time in operation.

Operating Report: This should show the amount of water used; the average feed water temperature; the average steam pressure; the average quality or temperature of the steam; the amount of fuel consumed; if the fuel is coal, the name of the mine from which it comes and an analysis and its heating value;

the thickness of fire carried; the average draft; the average temperature of the flue gases; the average percent of CO_2 in the flue gases and the percent of combustible in the ash. As many of these records as possible should be taken with recording instruments.

If there is a water purifying plant there should be a report on its operation which should show the amount of water treated, the amount of reagents used and the titrations of the water.

By having these reports and the economy report before him the superintendent can know just exactly at what efficiency the plant is being operated, and if the efficiency is not as high as it should be he has only to study his records to find what is wrong. Then immediate steps can be taken to correct matters.

The Economy report, mentioned above, is made up from the data shown on the other reports. It is principally a summation of the data and the results therefrom, arranged so that the conditions of operation can be quickly ascertained. It should show the following items:

Steam Pressure,
Steam Temperature or quality,
Percent of CO_2,
Temperature of flue gases,
Kind of coal used,
Heating value of coal,
Percent of combustible in the ash,
Evaporation from and at 212 deg. per pound of coal,
Boiler h. p. hours developed,
Boiler h. p. hours at rated capacity of boilers in operation,
Percent of rating developed,
Efficiency of plant,

Another advantage of the records is that when it is known that there are to be certain changes either in load, fuel, etc., the records can be looked up and the operation planned to give the best economy for the changed conditions, e. g., assume the coal is to be changed, if the new coal has been previously used, the superintendent can find from his records the proper thickness of fire to be carried, the proper amount of draft, etc., so that the coal can be burnt at the highest economy as soon as it is received.

In order to know the cost of operation it is essential to have a cost sheet. This should be based on the unit of output from the plant. This unit should be large enough so that the various items of cost will be great enough to have some significance. The unit also should take into consideration the feed water temperature and the steam pressure. A unit of 1000 boiler h. p. hours fulfills all these conditions. Having adopted a unit of output the next step is to get a cost sheet which will show in detail the various items of cost in the boiler house. For this the writer would suggest the following:

PRODUCING LABOR

Superintendence
Unloading fuel
Coal crushing
Firemen
Ash wheelers and conveyor tenders
Water and feed tenders
Boiler washers and cleaners
Attendance water purifying plant
Total Producing Labor

LABOR IN REPAIRS AND MAINTENANCE

Buildings
Coal handling and crushing machinery
Ash handling machinery
Stokers, burners, grates and attachments
Boilers and fittings
Steam mains and pipe covering
Feed water heaters and pumps
Water purifying or filter plant
Total Labor in Repairs and Maintenance

MATERIAL IN REPAIRS AND MAINTENANCE

Buildings
Coal handling and crushing machinery
Ash handling machinery
Stokers, burners, grates and attachments
Boilers and fittings
Steam mains and pipe covering
Feed water heaters and pumps
Water purifying or filter plant
Total Material in Repairs and Maintenance

LUBRICANTS
TOOLS AND MISCELLANEOUS SUPPLIES
TOTAL COST ABOVE FUEL
Tonnage of coal fired, gross tons
Average price coal per gross ton
Number of 1000 boiler h. p. hours
Cost of fuel per 1000 boiler h. p. hours
Grand total cost including fuel
Boiler efficiency

To make up this cost sheet the boiler superintendent will have to furnish the accounting department with the number of 1000 boiler h. p. hours produced in the boiler house and the efficiency of the plant. The accounting department will then divide the amounts of money expended for each item by this and the quotient will be the cost per 1000 boiler h. p. hours.

The boiler superintendent will find this cost sheet very valuable for it will enable him to know just exactly what it is costing to produce steam and also to work intelligently to reduce costs. Also in the case of improvements, this cost sheet will be found to be very valuable, for by having the cost for performing certain work with the present apparatus, it will be easy to arrive at the saving which can be made by the proposed change. Thus one can easily determine whether a proposed improvement will be a good investment and if the saving made will be a reasonable return.

Keeping the records and cost sheet as outlined will, of course, involve some expense and the question which will first present itself to ones mind is: Will the improvements in economy justify the expense and trouble? In order to answer this I will give two cases from actual experience. The first case relates to the operation of a water purifying system. The plant was installed in 1904. Until 1908 no system of reports or records of the treatment of the water was kept. During this period almost the only benefits derived were the neutralization of the free acid and possibly a slight reduction in the incrusting solids. In 1908 a regular system of reports was started and the treatment of the water was increased so that it was completely treated.

The following table shows the tube renewals per 1 000 000 boiler h. p. hours operated per year:

1907	49.83 tubes
1908	19.25 "
1909	6.59 "
1910	0.67 "

An analysis of the treated water in 1907 was as follows:

Volatile and Organic Matter	0.95	Grs. per	U. S. Gal.
Silica	0.45	"	"
Calcium Carbonate	0.16	"	"
Calcium Sulphate	3.18	"	"
Magnesium Carbonate	0.90	"	"
Sodium Sulphate	1.12	"	"
Sodium Chloride	0.49	"	"
Total Solids	7.25	"	"
Suspended Matter	0.90	"	"
Free Carbonic Acid	0.66	"	"
Incrusting Solids	5.64	"	"
Non Incrusting Solids	1.61	"	"

An analysis of the treated water in 1909 was as follows:

Volatile and Organic Matter	1.24	Grs. per	U. S. Gal.
Calcium Carbonate	1.00	"	"
Magnesium Carbonate	0.63	"	"
Sodium Carbonate	1.86	"	"
Sodium Sulphate	3.88	"	"
Sodium Chloride	0.49	"	"
Total Solids	9.10	"	"
Incrusting Solids	1.63	"	"
Non Incrusting Solids	6.23	"	"

From this it is seen that the full benefits from the system were not obtained until a complete system of records of operating conditions was kept.

The second case is that of a boiler plant which was being operated at an efficiency varying from 50 to 55 percent. In order to increase this it was decided to put a man in charge, whose duties would be to keep the plant operating at the highest efficiency possible.

The following is a brief description of the plant:

Fourteen water tube boilers equipped with chain grate stokers, coal and ash handling machinery, an intermittent water purifying system and auxiliary apparatus, such as Venturi meter, recording feed water thermometer, recording steam pressure gauge, recording CO_2 machine, damper regulator and feed water regulators.

The following shows the efficiency and actual cost of operation for an average month before and after the boiler superintendent had been put in charge. The month of March was before the man had been put in charge and January after:

PRODUCING LABOR	March 1910	January 1911
Superintendence	.....	.0566
Unloading fuel	.0504	.0334
Coal crushing	.0384	.0506
Firemen	.2206	.1992
Ash wheelers and conveyor tenders	.0744	.0653
Water and feed pump tenders	.1204	.0962
Boiler washers and cleaners	.0046	.0615
Attendance water purifying plant	.0691	.0607
Total Producing Labor	.5779	.6234
LABOR IN REPAIRS AND MAINTENANCE		
Buildings	.....	.0715
Coal handling and crushing machinery	.0086	.0024
Ash handling machinery	.0016	.0023
Stokers, burners, grates and attachments	.0045	.0014
Boilers and fittings	.0497	.0441
Steam mains and pipe coverings	.0063	.0023
Feed water heaters and pumps	.0033	.0046
Water purifying or filter plant	.0002	.0115
Total Labor in Repairs and Maintenance	.0742	.1403
MATERIAL IN REPAIRS AND MAINTENANCE		
Buildings	.0001	.0485
Coal handling and crushing machinery	.0070	.0053
Ash handling machinery	.0184	.....
Stokers, burners, grates and attachments	.0054	.0144
Boilers and fittings	.1062	.1174
Steam mains and pipe covering	.0146	.0182
Feed water heaters and pumps	.....	.....
Water purifying or filter plant	.....	.0042
Total Material in Repairs and Maintenance	.1517	.1968

LUBRICANTS	.0066	.0056
TOOLS AND MISCELLANEOUS SUPPLIES	.0316	.1085
TOTAL COST ABOVE FUEL	.8420	1.0746
TONNAGE OF COAL FIRED, TONS	4661	3878
AVERAGE PRICE COAL PER TON	1.5600	1.5600
NUMBER OF 1000 BOILER H. P. HOURS	1699	2031
COST OF FUEL PER 1000 BOILER H. P. HOURS	4.2797	2.9787
GRAND TOTAL COST INCLUDING FUEL	$5.1217	$4.0533
BOILER EFFICIENCY	53.3000%	62.0000%

From these figures it is seen that the efficiency of the plant has been increased from 53.3 to 62.0 percent and the grand total cost per 1000 boiler h. p. hours reduced from $5.12 to $4.05, or a saving of $1.07 per 1000 boiler h. p. hours. If we assume an operation of 7000 hours per year the saving would be $7.49 per boiler h. p. year. It is to be noted in the above figures that the total cost above fuel has apparently increased but that is not altogether correct. A small part of the increase is to be accounted for by the wages of the boiler superintendent, but the greater part is due to the fact that more money was expended for repairs and maintenance.

In conclusion I would state whereas the system as outlined seems somewhat elaborate, yet the results from systematic operation of the plant will be found to fully justify the trouble and expense. The two cases cited are not all extraordinary and it is the opinion of the writer that an investigation of an average boiler plant in industrial works will reveal even greater possibilities of improvement than of those given.

DISCUSSION.

Mr. W. E. Snyder*: I was thinking while Mr. Hunter was reading his paper of an investigation that was made by this Society about fourteen years ago to obtain some information on the cost of power in the Pittsburgh District. Blanks were perpared, and sent out by the Society, and manufacturers were requested to fill in these blanks giving certain information on costs of operating boilers and engines, as well as capacity, efficiency, etc. The responses that were made were most unsatis-

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factory. It was apparent that no one knew very much at that time about what power was costing, and had no data worth mentioning relative to the results that were being obtained from apparatus used in the production of power. In the discussion that ensued in the Society upon the receipt of these returns from the menufacturers, one mechanical engineer, of some prominence at that time, and connected with a large steel works, stated in substance that no one knew or cared very much about the cost of power, because it was only one item among a number of other items, all of which went to make up the total cost of production. The cost of power was buried with other items in the total cost of production, and that was the end of it. This I think in general was true at that time.

As indicating just what conditions did exist at that time in connection with the supervision of the generation of power, I can cite one instance which may seem to be exaggerated, though it is an exact statement of fact, and is typical of what was probably a very common occurrence at that time in a district of cheap fuel, and practically no engineering supervision in the operation of power equipment. There was a water tube boiler in the works of which I speak, which was hand fired by a very active and energetic little German. The greatest ambition of this small German was to get the stack red hot every day up to a certain point where he would make a mark with a piece of soap-stone. If he succeeded in getting it red hot to a higher point than what he had been able to accomplish previously, it established a new record, and he was correspondingly elated. This is indicative of conditions which were generally prevalent at that time, when most manufacturers or managers if they gave the production of power a thought at all, regarded it as the engineer above mentioned has expressed it: i. e., that the cost of power was only one item among a number of others going to make up the total cost of production, and on account of the fuel being cheap, it must follow that this item of power cost could not be reduced. If reduction in cost of production was to be accomplished, the labor item was usually the first one attacked, and wages were reduced, this, notwithstanding the fact

that fuel was being wasted in large quantities and the whole proposition of producing and using power was so inefficiently handled that a very large saving was possible in this item alone, thereby avoiding, or at least reducing, the reductions in wages which were thought to be necessary. However this describes a system of business management which is gradually being replaced by management conducted along scientific lines, one of the objects of which is to analyze carefully the various items which go to make up the cost of manufacturing a certain product, and to determine how far a legitimate reduction in these items is possible.

One of the large items in the cost of production is the cost of power, and one of the most important parts of this item is the cost of operating boiler plants; i. e., the cost of fuel and converting it into steam. The proper analysis of this power cost item, which includes the analysis of its various parts, such as boiler house expense, engine expense and the heat efficiency of this kind of apparatus, is the only logical way to make a reduction of the cost of power, and to this extent reduce the cost of the finished product. Mr. Hunter in his paper has discussed very fully the treatment of boiler house costs. I might, however, supplement his duscussion by an outline of the practice which has gradually developed in the American Steel & Wire Company, with which I am connected.

We have in operation between five and six hundred boilers, the larger number of which are water tube boilers. These boilers are distributed in the various works owned by the Company, these works being located in the northeastern part of the United States, from the Atlantic west almost to the Mississippi River.

We first made the endeavor to analyze boiler operating costs about the beginning of 1903. At that time there were no meters of any kind that were practical for regularly metering the water going to boiler plants, and in the effort to obtain a unit to which the various items of boiler house costs could be referred, we were obliged to take the only unit that was then available, that is, the ton of coal fired. The selection of this unit led to the criticism on the part of managers and superintendents of

works that the larger the quantity of fuel consumed, the smaller the expense per ton of the different items which go to make up the total cost of producing steam. In other words, the more coal used, the better the conversion cost, and in order to make a favorable showing of the conversion cost, it was advisable to waste fuel. To silence any criticism of this kind we developed the method of discussing and treating all boiler house propositions along three lines:

First: The selection of the proper fuel for the boilers, keeping in mind the location of the works with relation to its fuel supply and the character of the grates, boilers, etc.

Second: The maintenance of the highest possible thermal efficiency. This considers the boilers only from the standpoint of a heat apparatus used to convert coal into steam.

Third: The purely mechanical proposition of handling coal, ashes, and operating the boilers. This part has nothing to do with the kind of coal burned or the thermal efficiency of the boilers.

In the works located along the eastern seacoast we use either Pocohontas or coal from west central Pennsylvania, which is very similar to Pocohontas, and gives correspondingly good economy. In the works located in western Pennsylvania, Ohio, Indiana and Illinois the coal used is what might be regarded as the natural coal supply of these respective works. The coal must be located near enough to the works so that its heating value when considered along with its cost at the mine plus the freight to the works makes it a competing fuel. The most expensive fuel district is the New England States, with the plants located in Indiana and Illinois a close second. The works in Pennsylvania have the cheapest fuel; the fuel cost in Ohio being between the Pennsylvania plants and the western plants. While it is the endeavor of our Company to have good engineering supervision over the entire power proposition, we use more care in the selection and use of fuel in the districts where it is more expensive than we do in the districts where it is cheapest.

In selecting the coals for use in different boiler plants five series of coal tests were made: One at Worcester, Mass.; one at

Pittsburgh, Pa.; one at Cleveland, Ohio; one at Waukegan, Ill., and one at Anderson, Ind. These five series of tests include between 40 and 50 complete tests which were made in general as follows:

At least 100 tons of each kind of coal to be tested was obtained from the companies competing. Some of the 100 ton samples were taken under the supervision of our inspector, usually, however, the coal company was allowed to furnish the sample which it was willing to have regarded as a representative sample, it being understood that in case the company furnishing the sample should receive the contract the coal which would be furnished as regular supply would be equal in quality to the sample submitted for the standard test. Each test was continued for 120 hours, and was divided into five 24 hour periods, each of which was a complete test in itself. All important quantities, such as water, coal, ash, etc., was obtained by weighing; every possible precaution was taken to obtain correct and reliable results.

The average evaporation from and at 212 degrees per pound of dry coal for each 120 hour test was taken as the first basis of comparison. Separate samples of coal were obtained from the mines to determine the moisture in the coal as it comes from the mines, which is a very important matter with western coals where the moisture content is high. The evaporation from and at 212 degrees per pound of dry coal was then corrected for this mosture and a calculated evaporation per pound of commercially dry coal, or coal as it is weighed at the mines, was obtained. This was the final basis on which the coals were compared, and from this comparison tables of factors were calculated which can be used by the General Purchasing Agent in comparing the prices of coal submitted by the different companies; i. e., from these factors the Purchasing Agent may determine the price that he can pay for each kind of coal in order that the fuel cost for evaporating equal weights of water may be the same.

When the contract for the coal has been placed, it is then necessary to sample the cars as they are shipped to the different

works in order to see that the quality of the coal is up to the standard sample which was submitted by the coal company for test. In order to do this, in our eastern and western plants every alternate car is sampled according to a standard method. These samples are sent to a laboratory provided for the district in which the works is located, where the ash, moisture, sulphur and heating values are determined. Where the quantity of coal received is large the samples from several cars are sometimes combined, thus reducing laboratory work. The object of all of this, however, is achieved, which is to obtain at the end of each month the average ash, moisture, sulphur and heating value of the coal received. The methods described here are modified to some extent in the different districts depending on the importance of the fuel proposition from a cost standpoint, but the general plan is the same.

In addition to this we have in some districts specified certain mines from which coal is to be shipped and the shipping notices of each car must designate the mine from which it is loaded.

When these methods were first inaugurated, we became involved in various controversies with the companies supplying the coal, due always to the shipment of coal which was not up to the standard. In some instances rebates were allowed by the coal company, in one instance aggregating $12 000 at one time. After experiences of this kind some of the coal companies themselves established laboratories, and learned something of their own product. At the present time there is very little trouble as the coal companies are willing to co-operate and in general do not try to sell one kind of coal and furnish something else. In case any defective coal is received, the company shipping the same is advised, and they take the proper measure to prevent the continued shipment of fuel which is inferior in quality to what we have purchased. A knowledge on the part of the coal companies that their shipments of fuel are being sampled and records kept of the results of this sampling has much to do with the maintaining of the quality of the fuel up to the standard specified.

The large fund of data which was obtained in making the tests outlined above is very valuable for reference purposes when new companies desire to furnish coal, and there are no opportunities for making complete tests of the fuel from their mines.

So much for the selection of proper fuel and the maintaining of the regular supply up to the standard specified. The next point is the maintenance of thermal efficiency of the boiler plant. This means good and continuous technical supervision in order to keep all of the conditions such that the highest possible percentage of heat that is in the fuel will be transferred to the water in the boiler. It is necessary to keep the conditions of combustion good; i. e., proper air supply and high furnace temperature; to keep down excess air which comes through holes in the fuel bed on the grates or through cracks or other openings in the boiler settings; to prevent waste of unburned fuel in the ash pit; to keep the boilers reasonably clean inside and outside, etc. There have been developed within the past five years various kinds of apparatus, such as recording Venturi meters, continuous gas analyzers, pyrometers, recording thermometers, etc., which contribute greatly towards the maintenance of good thermal operating conditions of the boilers. The proper use of this apparatus, and the data obtained from it, will enable any superintendent, if he be guided by good engineering suggestions, to operate the boiler plant in a way that is much more satisfactory and efficient that it was formerly possible to do, no matter how good the intentions of the superintendent were on this point. The maintaining of the thermal efficiency as high as possible permits the ton of coal to be used as a basis of comparison of boiler house costs, and renders groundless the criticism that the more tons of coal burned the better the results from a conversion cost standpoint, because the conversion costs show the results, when the thermal efficiency is maintained, as good as is practically possible.

The next proposition in the analysis of boiler house cost is that of considering the boiler house simply as a handling proposition without regard to the thermal efficiency of the quality of the fuel. The cost sheet that Mr. Hunter has given outlines

fully all the items that go to make up the total cost of producing steam. It includes, labor, repairs, and miscellaneous items. Each one of these divisions being sub-divided so that it is possible to obtain the cost for all the principal kinds of work that is necessary in operating the boiler plant, and also the repairs of the main parts of the plant. In using this cost sheet the main thing is to get a good basis for comparison, as one of the valuable features of a cost sheet of this kind consists in its enabling comparisons to be made in boiler plants where the conditions are entirely different,—for instance, in comparing hand fired plants with other plants using chain grates, coal and ash handling machinery. As Mr. Hunter has stated, the proper way to view the boiler plant is as a producing department, exactly the same as if it were producing a product that could be sold by the ton. In fact, for some purposes we like to figure the value of steam per ton because in estimating savings which will be produced by making certain changes, this is a convenient way of determining the total cost of the steam which will be saved in a unit of time.

In the former part of this discussion I have referred to the use of a ton of coal as a basis of comparison to which the different items on the steam cost sheet can be referred. This basis, as stated, has been used for a number of years, and has proven very convenient and satisfactory, always keeping in mind the fact that the thermal efficiency of the boilers was maintained at as high a grade as possible. However, during the past three or four years the Venturi meter with integrating and recording apparatus has been developed to such a point that it is a very convenient and satisfactory means for determining the total water used for feeding the boilers. The Venturi meter is in general thoroughly reliable for this purpose. While I have never had the opportunity to calibrate any of these meters carefully myself, I have discussed it with superintendents and engineers in charge of plants where it has been calibrated, and the general consensus of their opinion is that it is entirely reliable. The plants where I have discussed with the engineers who used it are power plants in London, England, large power plants in

New York and in some of the plants of the United States Steel Corporation.

There is one difficulty which has been mentioned in connection with the reliability of a Venturi meter, and this we have experienced in some of our own works. Where the feed water contains much scale forming matter, and even in works where purified water is used, a deposit will sometimes form in the throat of the meter, which renders it unreliable. However, knowing that such a condition may occur, it can be guarded against by taking out the tube at intervals if necessary and cleaning it.

There are two other devices that have been developed for measuring or weighing feed water for boilers. One of these is the Weco water weigher, of which we have one installation in a plant of 3000 boiler h. p. It has not proven very satisfactory in its operation, and it has the added disadvantage of having to be located ahead of the heater so that the exhaust steam which is condensed in the heater to heat the feed water is not measured by the meter. My attention has recently been called to another device called the Lea water measuring apparatus, which is made on the principle of a weir, the head over which is automatically recorded in such a way that the curve represents the actual quantity of water flowing over the weir. While we have not tried this, it is evidently open to one criticism that I have made of the Weco weigher; i. e., that it does not include the condensed steam which is used to heat the feed water; this, of course, is measured by the Venturi meter which is located between the boiler feed pumps and the boilers.

The Venturi meter, as has been explained in the paper of this evening, gives a very convenient basis to be used in the steam cost sheet in analyzing the costs of operating boiler plants. It also gives the total water which is being fed to the boilers, and from this and the weight of the coal used, it is possible to obtain the over all efficiency of the boiler plant. This efficiency may, of course, not be strictly correct from an engineering standpoint, but for all commercial uses it is a very good figure to have. When a manufacturer sees that the efficiency of his boiler

plant is 70 percent it makes little difference to him whether it is 68 or 72 percent; he does know, however, that it is not 55 percent, which is the important thing.

The Venturi meter has another very important use, and this is to enable the superintendent of the works to operate the boiler plant in exactly the same way as he operates any other producing department; i. e., by having before him each day the average boiler horse power developed and the number of boilers in operation, he will know the average power produced by each boiler. After the best rating at which the boilers are to be run has been determined by test, the superintendent can then maintain the operating conditions of the boiler plant so that the best thermal efficiency will be obtained. The indicating dial of the recording device of the Venturi meter is a very convenient feature as it indicates at all times the rate at which the boilers are being fed, and if the scale is properly graduated into boiler horse power, anyone in charge at the works can always tell, when passing the meter, just what capacity is being obtained from the boiler plant.

As indicating what uses can be made of a meter when used for the purpose just explained, I can cite one instance of an experience at one of our works having thirty 250 h. p. water tube boilers. These boilers were hand fired, and the management in charge of the works were very earnest in their request for additional boiler capacity as there was difficulty in maintaining steam pressure. No additional boilers were put in, but the boilers in the plant were equipped with chain grates, and in addition to this the boiler plant was equipped with a Venturi meter. The result was that in place of requiring additional boilers, it is possible to operate with some six or eight boilers out of commission undergoing cleaning and repairs. Part of this, of course, is due to the fact that under the hand fired conditions there would always be at least three boilers which were not working up to nearly their full capacity. One would be burning down for cleaning; fires were being cleaned on the second boiler, and the third would have a fresh fire. The use of chain grates, of course, avoided all of this and at the same time enabled the boilers to be operated at a higher capacity and still

maintain the efficiency. However, a large part of the improvement in capacity was due simply to the use of the Venturi meter, as the Superintendent of the works required the Master Mechanic who had charge of the boilers to furnish him each morning a statement of the average boiler power developed, and the number of boilers in operation on the two previous turns. After it had been determined that a high capacity was better for the economy than running at or under the rating of the boilers, the meter made it possible for the Superintendent of the works to operate the boilers at approximately the capacity which had been determined by the engineer as the best rating from an economical standpoint. The superintendents of works operating their boiler plants in this way, handle boilers in exactly the same way as they do any producing department which produces a product that is sold. Therefore, the use of the meter really serves three different and important purposes: It furnishes a standard or basis for analyzing and comparing steam cost sheets; it enables the calculation of the commercial or working efficiency of the plant; and the records from the meters, together with the various other records which have been mentioned in the paper this evening, enables the Superintendent to operate the boiler plant himself, and not leave it, as was formerly the case, to the caprices or vague ideas of a machinist, or in some cases a water tender.

The question of the supervision of boiler plants that has been mentioned in the paper and also in this discussion, is a difficult one to handle for the reason that no matter how the plants vary in size, they present very similar phases of the same problems, in operating them. These problems relate to the safety, and also to the economical operation. First and foremost, all boiler plants should have technical supervision at least in an advisory capacity, so that when changes are made or when any important emergencies arise, there will be someone with a broad experience who will supplement the knowledge that is available at the works where the boilers are located. In some cases, this is the boiler insurance company's inspector; in other instances, it is the mechanical engineer of a company operating

possibly many boiler plants, or it may be a combination of these two heads,—which is usually better than one. In any case, however, there ought to be technical supervision not only because of safety conditions, but because economy considerations also demand it.

Granting that there should be technical and high grade supervision, another difficult phase of the supervision proposition is in obtaining a man of the right capacity and ability for immediate charge of the boilers. This is a difficult proposition for several reasons. At industrial works, the boiler plants are usually too small to permit the employment of a high grade, technically educated man in immediate charge of the boilers. In many instances the boiler plants are so small that even the employment of a first class boiler house foreman does not seem warranted. Right here is where the steam cost sheet and the meter records again come into very good advantage. It is possible, as shown in the paper this evening, to show clearly, in terms of dollars and cents, just what has been accomplished by placing a capable man in direct charge of a boiler plant. I have no doubt that there are many boiler plants now in operation without an efficient foreman in charge, where it could be shown by proper meter and other records that the investment required to obtain the services of a good foreman yields return larger that could be obtained on a similar investment for any other kind of a change in the whole power equipment. As more attention is given to this matter in the future, of course, these conditions will gradually improve, and more capable men will be put in immediate charge of boilers, but the point which is made here is that the keeping of such operating data as has been outlined and described, together with the use of meters in boiler plants, will contribute greatly to bringing this improvement about.

I could go on with this discussion to a considerably greater length but feel that I have already taken up too much of your time as there are others to speak. However, I can say this very emphatically: While I do not feel at liberty to quote actual figures in a discussion of this kind, I believe that I have not

made any statements which I cannot substantiate by figures from past experience that are entirely reliable. That such methods as have been outlined in Mr. Hunter's paper, and as I have discussed above, do absolutely pay in dollars and cents, there is no question or doubt in my mind. The only way of attacking such a large problem as the cost of power in large industrial plants is by dividing it into parts such as boiler expense, engine expense, etc., and then in turn sub-divide these; as for instance, sub-dividing boiler costs into fuel and operating expense, and still further sub-dividing operating expense into its various component items, and investigating in detail each one of these various items. The result of this is good, not alone from an operating standpoint, but as a guide to an engineer in making future installations by knowing the operating costs in all their details of the installations which are in actual service.

Mr. J. H. Vance: The paper has been very interesting. There is one point I would mention. Where we put in meters to register the amount of water going to the boilers we lose sight of the fact that a good deal goes out at the steam pipe. We have just been going through a little line of work at our plant to eliminate this moisture, and bring our steam down to a little better than 99 percent dry. We are operating Sterling boilers and have had rather wet steam.

The dry pipe we have installed has given us steam which we know is 99 percent dry. From my experience at the boiler end I believe that is one of the places where we can save a lot of money if we can keep the heat where it belongs.

Mr. Reno Benner: What effect do feed water regulators have on Venturi meters?

The Author: When we first installed Venturi meters in small plants we had more or less trouble due to the fact that the feed water regulator caused the water to come in large quantities and then practically shut off. We overcame this difficulty by throttling the valve in the steam line to the pump so that the pump could only run at a certain fixed speed, and also throttling the individual valves to the boilers so only a certain

amount of water could be supplied at a time. By this method we practically eliminated all difficulty.

Mr. H. C. Cronemeyer: How do you take regular account of the amount of water blown out through the blow-off, how do you estimate it? Sometimes the boiler man likes to put one over on the accounting department. I know of one case where they measured the water pumped by the feed water pump revolution counters. I noticed one day the record showed an unusual increase and asked an explanation of the engineer. He said "We have a lot of boilers out of operation and I filled them all and tested them and didn't say anything because we wanted to know if you would find it out.

The Author: We endeavor to keep a record of the number of boilers filled and make reduction for the amount of water required to fill the boilers. For blowing down we estimate the average amount blown down each time and keep a record of the number of times each boiler is blown down. Of course if you blow them down you get an apparent evaporation that is not correct.

Mr. J. H. K. Burgwin: In furthering Mr. Hunter's last remarks I would say that I have never found a blow off valve that would not leak. Using two valves on the same line is an advantage as both are not likely to leak at the same time.

Mr. A. L. Hoerr*: It has always seemed strange to me that so many superintendents of rolling mills do not hesitate to have all sorts of reports prepared about the steel production, such as delay reports showing the character and duration of all the delays in hours per day, reports giving the exact tonnage for each hour of the day, the amount of scrap produced, the exact weight of the billets and slabs that come into the mill, etc., because he is very anxious that his record of steel production shall be correct and he believes these reports are necessary; but when it comes to making some record of the operation of his boiler

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plant he is quite indifferent. As has been said by a previous speaker, he is satisfied if at all times he has enough steam to keep the mill running and is almost indiffierent to how much it is costing him per unit of steam. I believe however that a very different feeling is prevailing now and the absolutely necessary thing is a system of reports such as shown by Mr. Hunter so that as a producing department you can know as nearly as possible what raw materials go in and what finished product comes out.

Our practice is very similar to that outlined by Mr. Hunter. As for Mr. Cronemeyer's question, we have a boiler report on which each boiler is recorded for the month as being blown down so many times and being filled a certain number of times. The amount of water blown down has been determined by frequent trials by measurements on the gauge glass. While this is of course only very approximate, it is very much better than ignoring it altogether. By this method we secure a fairly accurate record of the actual amount of water that passes through the boiler. Of course as Mr. Vance stated a great deal of that water goes into the steam lines and we can not always prevent that. But the time may come when with other boilers, as Mr. Vance has done with his Sterling boilers, we can prevent that water from leaving the boiler.

At the last meeting of the American Society of Mechanical Engineers the question of gas engines versus turbines was a very lively one. In answer to a question one of those interested in discussing the gas engine stated that in making his figures he allowed a boiler efficiency of 60 percent for gas fired boilers, that is in figuring the possible efficiency of a turbine plant he credited the boilers with an efficiency of only 60 percent. Now while it is very true that very many of the blast furnace gas fired boilers are operating at 60 percent, or less, it is also true that many are operating above this figure and there is no reason why that efficiency should not be exceeded by nearly all plants in the near future. A system of records, such as given by Mr. Hunter, and a careful system of supervision over such boiler plants will tend to raise their efficiency by showing up the weak points, when the remedies are easily applied.

Mr. Shook: I find in Mr. Hunter's paper that he has emphasized the idea of keeping records in the plant more than he has the efficiency of boilers, etc. As an engineer of a small plant, not 5000 but 250 h. p., I find it of great advantage to keep as close a record of all things pertaining to that plant as I possibly can. I find it also excites the ambition of the engineers in attendance to get better results in the plant all the way around. They will watch the coal and gas, the boilers and the output of amperes or whatever it is you are producing, and at the end of the month we carry along about the same amount of fuel and it corresponds exactly with the ampere load. In a small station it seems almost nonsense to keep records but I find it is to my advantage in a great many ways to have these records. When the engineer gets a little careless and opens up the draft a little wide, or burns 20 000 or 30 000 cubic feet more of gas, or the equivalent of that in coal, in a few hours, if it were not for these records I would not know anything about it until I figured up the fuel bill at the end end of the month. Also if the engineer leaves the blow off valve open a little too long the record shows there is something wrong and we hunt it up and find out where the trouble is. And just by having a leaky valve in a boiler we may lose 5000 cubic feet of gas in eight hours. I have kept these records for the last fifteen years because I want to know everything that goes on in the plant and I would advise superintendents and engineers in small plants to watch every little item and one can make a saving just as well as the big fellow can.

Mr. C. B. Albree: I am glad to hear some of you talk about the small plant, because we do not all of us have big plants. I have a small plant. We operated our boilers with natural gas for a while and found it was costing too much and decided to run on coal. We ran on coal about two years, operating two boilers, pushing them pretty hard, and we found our coal bill was running too high and we went back to gas. We put in an arrangement to burn gas in such a way as to give us very good heating capacity, but the gas would give out and we would have to tear that mass of brick out and use coal, meantime the

shop would be shut down two or three hours. So we got up a scheme to utilize the gas so that we could use coal if we wanted to at the same time without tearing anything out. After working on it a while we found we had to change our bridge wall—we had the ordinary horizontal return tube boiler—from a straight to a curved bridge wall about five inches away from the surface of the boiler. That gave us very much better results. We also found that by using coal and gas together our total bill for fuel was only about two-thirds of what it had been with either gas or coal. We have been using this combination for four or five years, using a thin bed of coal with enough air underneath to burn it and burning three jets of gas with the bridge wall close to the under side and another bridge wall six or eight feet back coming within 10 in. of the shell to keep the flames well up against the boiler and having absolutely no smoke.

Mr. W. E. Snyder: One thing that should be kept in mind in connection with attempting to analyze the cost of operating boiler plants is the difficulty of basing any conclusions regarding boiler house costs on the steam charged to the different kinds of product. Almost all boiler plants have several steam users drawing from them, and someone is obliged to make the distribution of steam among the several consuming departments, so that each department using steam from a boiler plant will pay approximately its share of the cost of producing the steam. Anyone familiar with the operating conditions in large works will realize the difficulty in making a steam distribution which would even closely approximate the true conditions, and make the charge to each consuming department exactly proportional to the quantity of steam used. This always makes some uncertainty regarding the steam charge per ton of product.

In one large works with which I am familiar, there are about 12 000 h. p. of boilers. This boiler plant supplies probably 40 different producing departments, all of which must bear the cost of operating that boiler plant. It is apparent that this brings in the very difficult question of proper steam distribution and the charge per ton of steam for different products will depend upon the kind of distribution that is made. Therefore,

any opinion regarding the boiler house costs that may be formed by observing the steam charge to one or more of the products made, may be changed entirely by a change in the method of making the steam distribution without regard to any change in the total boiler house costs.

The only possible way to handle a case of this kind and to be sure that the boiler plant is running under good economical conditions is to keep careful records of what the plant is doing, and at the same time have the cost sheet for each plant show in detail the cost for its operation. By examining the boiler house records and this steam cost sheet, it is possible to make a very good analysis of the conditions without any reference whatever to the steam charge per ton of product.

Mr. Vance: In line with the last gentleman's remarks, a friend of mine is operating a large steam plant supplying power. One of their tenants is a laundry man. They made him a flat rate of $100 a year for steam and later put in a meter and found that he was using $360 worth of steam per year.

Mr. Snyder brought out a point I want to emphasize in regard to the efficiency of the boiler room. We employ the best feeder available and put the best paid man on the job in as fireman to handle the boilers. The superintendent of boiler house is a busy man and we have been looking recently into the matter of equipping our plant with recording devices to get at our costs. It occurred to us that it would be better to put an individual meter on each boiler rather than one meter on the whole plant, then we could measure our water and our coal and the fireman was paid on the basis of output, in other words on a piece work basis, so much per thousand pounds of steam and then so much for every pound less coal that he burned to produce that steam. In that way we can make our firemen interested enough to become educated. As it is now we pay them $2 a day, while if they were on piece work where everything they did affected their pay we would get results. I would like to ask if any member here has had any experience in that line.

Mr. A. Stucki: I noticed what Mr. Snyder and Mr. Albree said in connection with small plants. It is true it is not always

convenient to put these different recording devices in and as a matter of course, they in themselves do not make things better but simply give us a key to what we are doing. We also have another key which does not cost us anything; namely, the smoke stack. When we see black smoke going out at such a rate as we often see I think we have means right there to know that something is wrong.

True enough, black smoke is a key to the combustion only and does not give any information as to the other boiler conditions but fuel economy depends more on proper combustion than anything else, and if provisions are made to this effect and if the firemen are then encouraged to avoid the black smoke the largest item in boiler economy is won.

Mr. A. L. Hoerr: Regarding the equipping of small boilers with meters I would think that in a large plant where you have possibly 40 or 50 boilers it would be a complication that would hardly be justified by the results, with any type of meter with which I am familiar. The object of the meters as now used is to give us the total water going into the boiler house. Our system in use at present takes each boiler house as a unit and the total water going to that house is measured. That makes the house a producing unit just as you would have a plate mill or a beam mill or a bar mill a producing unit with a separate cost. There may be developments of simple and cheap meters later which would enable us to get the output of each boiler separately. That of course would be an ideal condition, but I would not consider it a good thing under present conditions at such plants as are found around steel mills.

Mr. F. R. Low:* The interest and attention of the engineer has largely and naturally been attracted to the engine room, with its interesting machinery and attractive problems of valve design, setting, etc., but it has of late been borne in upon the man who paid the bills that one man with the ambition of Mr. Snyder's man to get his mark higher up on the stack each day can waste more coal in the boiler room than the most scientific engineering and the most refined type of apparttus can save

*Editor, Power, New York, N. Y.

in the engine room. There has arisen a lot of combustion engineers who have developed that indicator of the boiler, the CO_2 recorder, and there is today a station near New York in which the boiler room will be fitted with a bridge, where a captain will be in control of the boiler room operations. He will have before him, just as a man in the switchboard gallery at the electrical end of the station has all his electrical apparatus, all the apparatus upon the indication of which the operation of the boiler room depends. Indications will be constantly before him of his steam and water meters, pressure gages, draft gages, CO_2 recorders, etc., so that he can have, not only a record continuously made of what goes on, but it will be going on constantly before his eyes. There will be also on the wall at the end of the boiler room a big sign, which will read in electrical letters "The steam pressure is now steady," or "going up slowly," "going up fast," "going down slowly," "going down fast," etc. This will change every twenty seconds, so that the men on the floor will have constantly before them an indication of how things are going, and will not have to watch the gages.

I should like to get some more information in regard to the efficiency which is obtainable by the use of blast furnace gas under boilers, a matter to which Mr. Hoerr referred. We have figures from the Redondo station in California, where with oil-fired boilers they have obtained efficiency over 80 percent. You have here conditions which should be favorable for high efficiency, and I should like to know if anybody has obtained any figures upon the subject.

I should like to know also how much coal is used in connection with gas, where the gas is fired over a grate, upon which a coal fire is maintained.

There has been attention directed also to the upkeep of the furnace. I think the author of the paper referred to this under the general heading of repairs, but engineers have found in trying to get a good deal out of their boilers on the peak of the load that they can get 200 percent of the rating, without falling off more than five or ten percent in efficiency, and that five or ten per cent loss in efficiency does not count for much beside

the standing losses of an extra boiler. So there is a disposition to crowd boilers much more than the ratings that were recognized as common two or three years ago. The limiting factor in that direction is the furnace. How much firebrick can you afford to burn up? Any particulars in regard to furnace costs and the cost of putting in an extra good firebrick as against an ordinary firebrick, the amount of service you can get out of it at the comparatively smaller cost of the other material in place; all these are data which are being looked for with a great deal of interest by engineers.

I notice that the author proposes as a term for the expression of boiler efficiency the "thousand horsepower-hour." I hope that the boiler horsepower will be discouraged as much as possible as an unscientific and archaic term. It would be much better expressed in the cost of evaporating 1000 pounds of water, a ton of water or something of that kind.

Mr. A. L. Hoerr: Referring to Mr. Low's question as to the burning of gas I would say that the best tests that we have had in our plant, and they are not so very good, is at 150 percent of the boiler's rating an efficiency of about 63 percent. Those are figures that were obtained from settings as they were built some years ago and without any special preparation for getting good efficiency. Mr. Leahy who is here can possibly add something on this point as he has done some work in the burning of blast furnace gas with special furnaces.

Mr. F. E. Leahy: We have made a number of investigations on the combustion of blast furnace gas, our object being to increase our boiler fire-box efficiency. Through this work we have developed a furnace in which no coal is burned, our experiments being against the use of the two fuels together. The boiler is the ordinary Babcock & Wilcox boiler, with a combination fire-box, allowing the burning of coal on grates and fired from the sides, and the admission of blast furnace gas in front. We found that under the best conditions, the air leakage from the sides through the fire-box was excessive, so we removed the grates and bricked up the sides and reduced the excess air,

which is one of the numerous causes of low efficiency in most blast furnace gas fired boilers. We then devised a method of passing the air to the gas in such a way as to preheat it and then mixed it with the gas in the front of the boiler. It then passes to the rear, where it is conducted into an enlarged chamber for the complete combustion to take place. The temperature of this chamber as observed by a pyrometer, was nearly constant at 2100 deg. fahr.

The stack gas showed an average of between 19 and 20 percent of CO_2. We have these fire-boxes installed at the Clairton Works of the Carnegie Steel Company, and they have now been in operation about three months. We have reduced our coal fired for steam purposes at our coal fired plant, which is connected to and part of the system, about 20 percent since the installation of this method of burning the gas.

Mr. W. E. Snyder: With reference to the use of individual meters for each boiler, a difficulty which we experienced when we attempted something of this kind sometime ago was to obtain any meter that was satisfactory for hot water under pressure. They all proved either to be unreliable at first, or to become so soon after they were put into service.

Apropos to this discussion on boiler house economy is a rule which I recently saw in a technical journal which gives a new method for determining the heating value of coal. This rule, which it was said some practical operating man had developed, was to multiply the pounds of coal in a railroad car by the price per ton and divide that by the railroad car number, the answer being the B.t.u. per pound of coal. *Q . E. D.*

Mr. Vance: Could the Venturi meter be used as an individual system to advantage?

Mr. W. E. Snyder: I am afraid not. There would be too much difficulty in taking care of a multiplicity of meters with their necessary recording and integrating devices. In addition to this, it would be a very expensive proposition as the integrating and recording mechanism, which is the most expensive part of the whole equipment would have to be purchased for each

boiler. Viewing this from the standpoint of both cost and operating conditions, I think it would not be a practical plan.

Mr. Smith: I believe the question about individual meters might be answered in this way. You would not expect to put individual meters on each boiler even if you had a large plant. You could equip the plant with meters for each 1000 h. p. of boilers, or whatever number of boilers is taken care of by one fireman. You could still keep your firemen on a piece work basis by putting in meters enough to cover the boilers one fireman takes care of.

The Author: With reference to the unit suggested by Mr. Low to take the pounds of water evaporated instead of boiler horse power hour, unless you specifiy that the pounds of water evaporated are from and at 212 degrees or some other point it would not mean very much in the way of comparison. And if you do specify 212 degrees you have only to multiply by 34½ to get a boiler horse power hour. So I do not see that there is very much difference whether you use boiler horse power hour or some other unit which practically means the same thing. And as we are all familiar with the term boiler horse power hour it would seem to me that that is a better unit.

RELATIVE ADVANTAGES

OF GROUP AND INDIVIDUAL MOTOR DRIVE AND THE COST OF INDUSTRIAL ELECTRIC POWER

By C. W. Drake.*

Motor drive is not as some people are inclined to believe, a panacea for all industrial ailments, although there are but few plants in which motor drive properly applied will not improve conditions. Hence it may ordinarily be assumed that motors are to be installed, and the questions to be settled are: What type of drive to use, and whether to generate the power or to purchase it from a central station. It is not the purpose of this article to attempt to show how to lay out an electrical equipment for any special industry, but rather to call attention to some of the more important factors bearing on the type of drive to be used, and the power supply.

Motor drives are installed because they produce a greater profit in the industry, and not because they are the ruling fad. Increased profit may result from increased quantity, improved quality, reduced power consumption or a combination of these conditions. Consequently, before any action towards the installation of motors is taken, figures should be available showing what may be expected in the line of first cost, power consumption, maintenance, and improved manufacturing conditions from several systems of drives.

There are two general systems of drive; namely group and individual, and the choice between these two for various applications is often a question of dispute. The power cost in most industries is less than 5 percent of the total manufacturing costs, so that a slight increase in production will quickly offset

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a large saving in power and consequently the item of prime importance in laying out motor drives is production, and after all items bearing on it are taken care of, the question of power cost and type of drive may be considered. Each installation is a separate problem in which there are many factors and the degree in which one or more of these various factors predominate, determine the type of drive to be used.

Outside of factors bearing directly on production, other points to consider when comparing group and individual drive are:

1. Investment
2. Rate for power
3. Machine load and time factor
4. Shafting friction
5. Maintenance

Investment is one of the principal factors that prevent the installation of individual drives, since this figure can be quite accurately determined while the saving in energy is more or less approximate and problematical.

With individual motor drive the total horse power rating of the motors installed in a plant will be considerably greater than with group drive, but the maximum power demand of the plant is approximately the same in either case. Some power contracts with central stations are based on the horse power connected, or on the maximum demand considered as a certain percentage of the connected load. It is easily seen that a rate basis as above would tend to prevent the installation of individual drives since a group drive would obtain a lower basic rate, although the high efficiency of the individual drive would tend to reduce the actual power consumed. A more logical basis of charging for power would be on the actual maximum power demand which is either estimated or obtained by test, together with the actual energy consumed. On this basis the individual drive by reason of its lower transmission losses will show a lower power cost than the group drive.

In group drive there are two distinct loads, the variable load of the machines and the friction of the shafting and belting. The lower the machine load factor, the greater becomes

the percentage of the friction load and the more inefficient the transmission.

In order to show more clearly the relative advantages of individual and group drives, an example has been made of an existing planing mill. At present a 20 h. p. 840 r.p.m. squirrel cage induction motor is installed driving eleven machines by means of a 60 ft. shaft (eight hangers) and six 2-hanger countershafts. The cost of the 20 h. p. motor for group drive is assumed as $297, and cost of the shafting and hangers, in place, as $210.

If, on the other hand, the eleven machines were operated by individual motors, the following table shows the size and speed that would be recommended for each machine.

Machine	Motor	
	H. P.	R. P. M.
30-in. single surfacer	7½	1120
8-in. four side moulder	7½	1120
16-in. hand feed rip saw	5	1700
20-in. swing cut off saw	3	1700
Single spindle shaper	3	1700
18-in. jointer	3	1700
Tenoner	3	1700
Mortiser	2	1700
Jig saw	½	1700
Drill	½	1700
Double emery wheel	½	1700

The cost of the eleven motors for individual drive is approximately $848.10. The fixed charge has been figured as 15 percent, which for this class of service should cover depreciation, interest, taxes and insurance.

It is assumed that with individual drive when the machines are not running the motors are shut down, while with group drive the belts are on loose pulleys. The proper motor losses have been added in each case. The friction loss in each bearing is figured as 100 watts and an idler pulley is considered as a bearing. The actual load on the machines has been assumed the same with both drives and consequently is neglected. Figure 1 is based on the above assumptions and shows that for the

plant in question the fixed and operating charges are lower for the individual drive, regardless of the machine hours per day, although for long hours of service the difference between the two drives becomes less. Practically all of the advantages from a production standpoint are with the individual drive so that

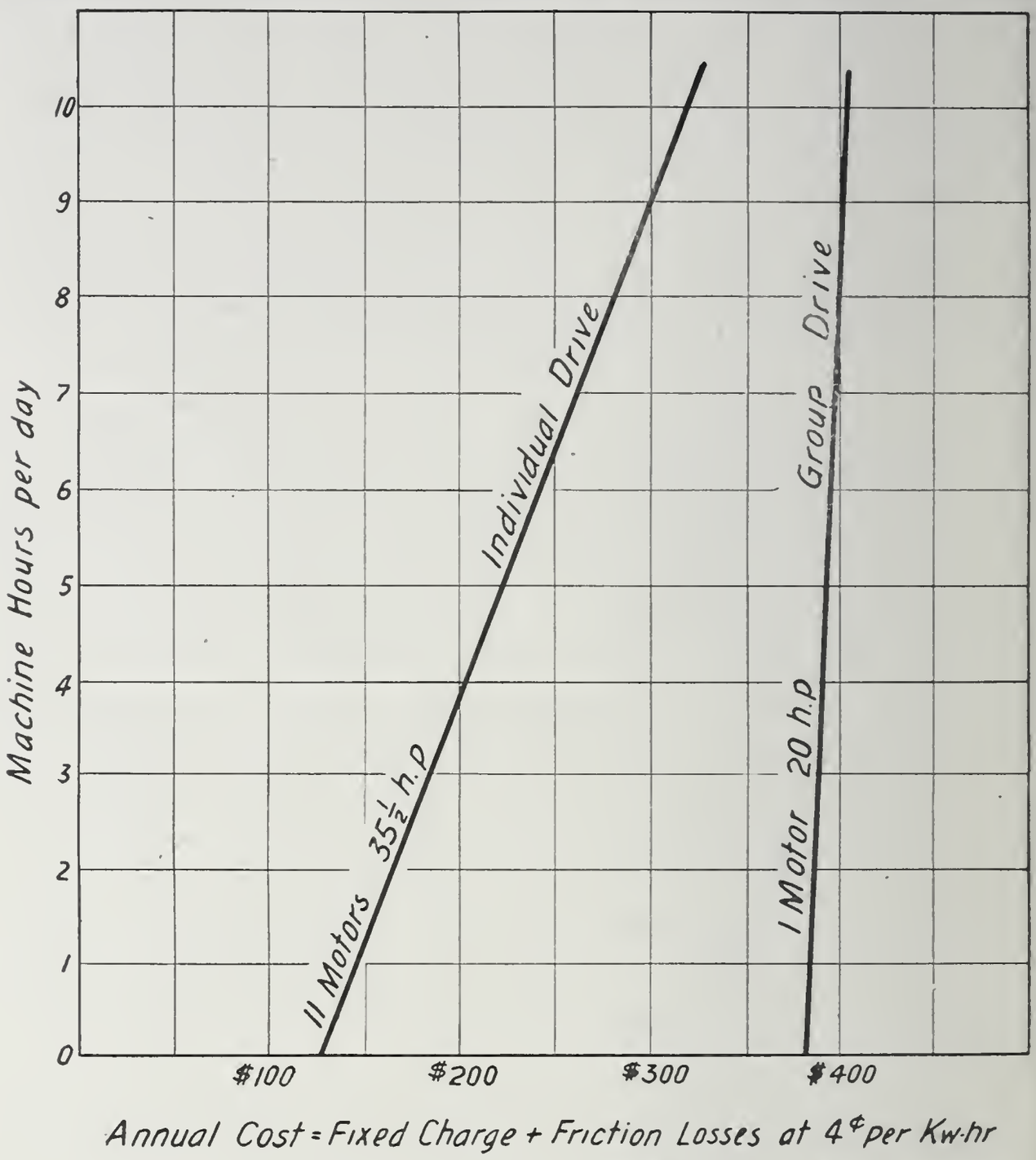

Fig. 1. Relative Annual Costs.

there is very little excuse for using group drive in this case.

Figure 2 is an extension of Fig. 1, and has been made to show the effect of the power rate on the relative advantages of the two systems of drive for various hours use of machines per day. From this curve it is seen that if all the machines worked

six hours per day, or had a time factor of 60 percent, that for all rates of one cent and above the advantage is in favor of the individual drive. For long hour service and very low rates the group drive has a lower total cost.

Both of these curves show that there is no sound reason for using group drive throughout in planing mills, and the example taken is entirely characteristic of this class of plants. Of the five factors mentioned in the early part of this article, all but the last one, maintenance, are graphically represented in Figs. 1 and 2. The plant with group drive has a total of 72 ft. of shafting, 20 hangers, 11 idlers and 18 belts, while with individual drive there would be at the most 11 belts and no overhead hangers or belts. To any one familiar with shop maintenance it is not difficult to see on which side of the book the balance for maintenance will be.

Although a concrete example was taken in order to obtain definite figures for the curves the same reasoning might be applied to plants of any size or in any industry. In large plants both individual and group drives are often used, the choice depending on the nature of the work done in the machines, the number of hours use per day and other factors as previously mentioned. It should be always borne in mind that the question of production predominates but that the actual power saving in individual drive by eliminating shafting and belts is sufficient to pay much more than the fixed charges on the increased investment.

THE COST OF POWER

This subject has been so thoroughly discussed and explained in recent periodicals (Cost of Industrial Power by Aldis E. Hibner and Comments on Fixed Costs in Industrial Power Plants by John C. Parker, Trans. A.I.E.E. March 1911; Notes on Factory Power Costs by H. H. Holding, Electric Journal, June 1911), that there is little new to add to the subject but at the same time it is of sufficient importance to warrant a review at this time. For the power supply for any industrial plant there are two possible sources; a private plant or a central station. In most cases there is no question regarding the relia-

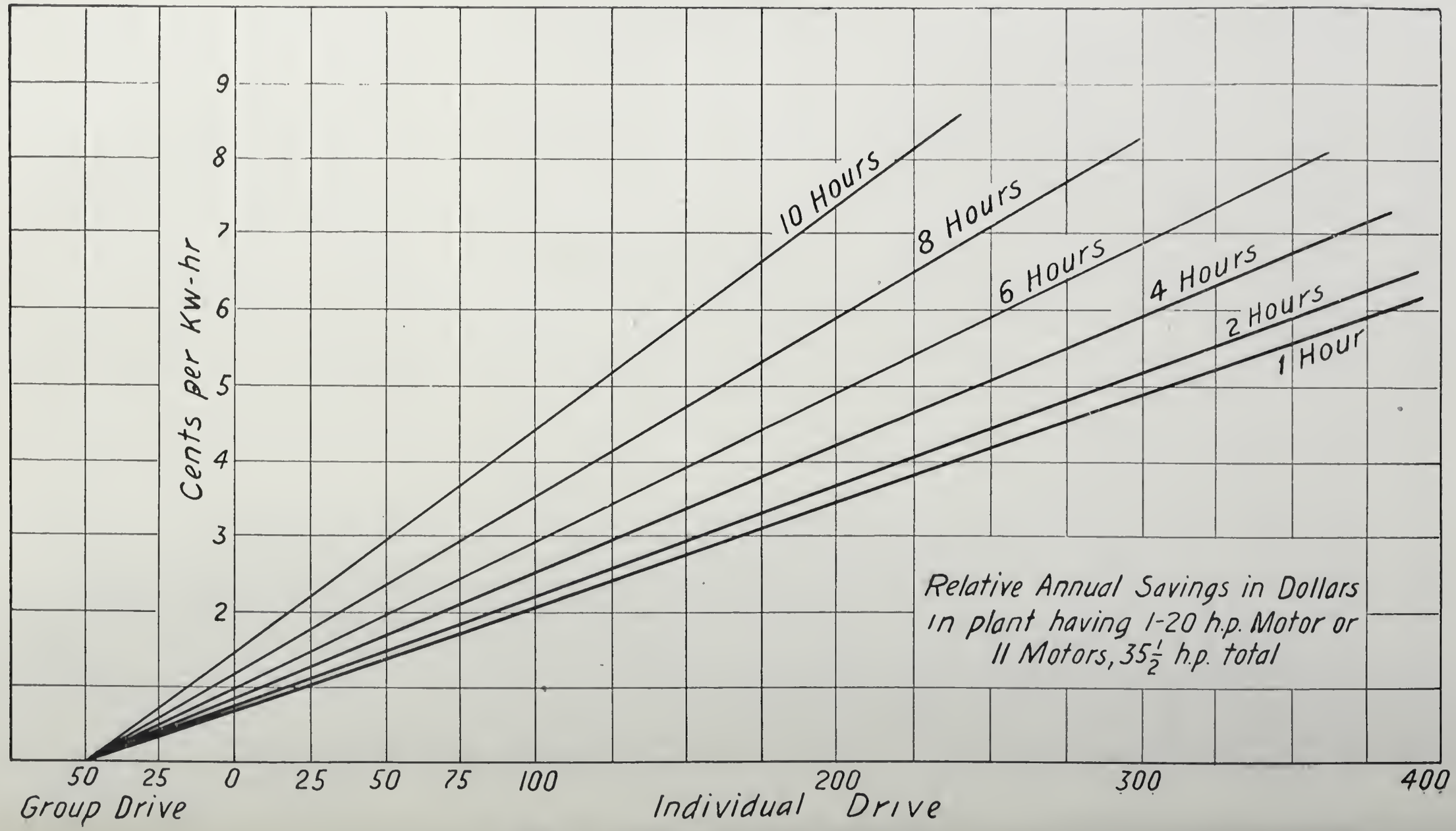

Fig. 2. Relative Annual Savings.

bility of the central station power and the only factor tending to retard its use is the rate. Owners of private plants often declare that they can make power much cheaper than they can buy it from a central station. The reason for this statement is in most cases that the owner of the isolated plant really doesn't know what his power costs him. The central station exists solely to manufacture and distribute power and has an organization especially trained for that work. The owner of the isolated plant is in business to manufacture some commodity and the manufacture of power is entirely outside of his regular business. His time could be spent to much better advantage in the business for which he is specially trained and which is producing dividends for him. Why should he manufacture electric power any more than manufacture his own gas, or pump his water when all are available and delivered at his door, with service which is both reliable and economical?

The cost of power may be readily divided into two parts, one covering the fixed charges and the other the variable or operating expense. Many people are accustomed to consider the fixed charges as negligible or if they do consider them, to omit many of the important items. The private plant must be of sufficient capacity to supply the maximum demand, and the load factor, or ratio of the average to the maximum demand, varies from 5 percent in some planing mills to nearly 100 percent in electrolytic work. Hence in most plants the generating equipment is working at a fractional load most of the time.

Looking further into the investment we find that the first cost of the plant should cover the cost of the land, buildings, prime movers and generators, boilers or gas producers, and auxiliaries such as pumps, piping, switchboard, cables, etc. The yearly charges against the investment are made up of depreciation, interest, taxes, insurance, rental value of ground, etc.

Large central stations with most improved machinery may be installed for $60 per kw. but for small industrial plants say of 100 kw. capacity the investment may reach $150 per kw. Let us consider for example a 100 kw. steam engine plant having an investment of $125 per kw. and a yearly charge of 17 percent or $21.25 per kw. This charge is made up of depreciation 8

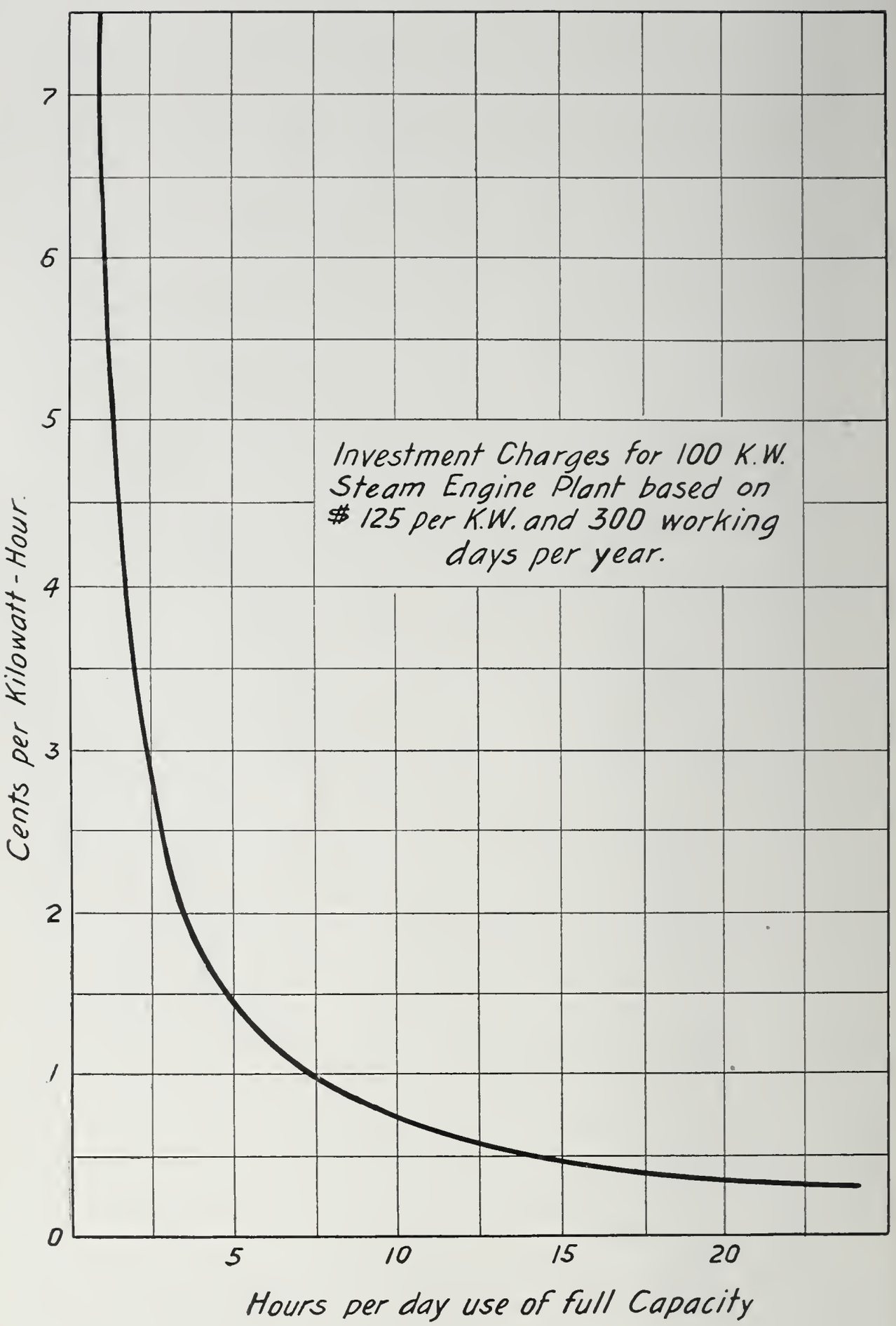

Fig. 3. Investment Charges.

percent, interest 6 percent, taxes, insurance, etc. 3 percent. Some people are inclined to allow even greater than 6 percent interest since the power plant is part of the factory and money invested there is expected to produce better than 6 percent.

On the basis of 300 twenty-four hour days per year of full load operation, the investment charge is 0.295 cents per kw-hr. Figure 3 shows how the charge per kw-hr. increases as the hours of full load operation decrease. For ten hours of full load operation the cost per kw-hr. due to investment is 0.708 cents. As previously stated very few plants operate at 100 percent load factor so the above charge must be corrected for the existing load factor.

In Fig. 4 the effect of plant load factor on the investment charge is shown and is based on full load operation for ten hours per day. Since only one generating unit is considered in the present case the variation in load must be taken care of entirely by the governor so the coal consumption is shown as increasing with decreasing load factor. A full load efficiency of 8 lb. of coal per kw-hr. is assumed and a rate of $1.50 per ton for coal, which is a fair average for Pittsburgh and vicinity. Another fuel curve based on coal at $3.00 per ton is also given together with a total cost curve under these conditions. From the two total cost curves it is seen that at 60 percent load factor a reduction of 50 percent in the price of coal reduces the total cost of power about 21 percent.

It has been considered that an engineer with a salary of $75.00 per month could operate the plant and that the incidentals as oil, water, waste, etc. would average $20.00 per month.

On the above basis the four curves for fuel, investment, labor and incidentals have been plotted and total power cost is the summation of the four. With a load factor of 100 percent for ten hours the power cost (coal $1.50 per ton) is about 1.7c per kw-hr., while for a 60 percent load factor it is 2.6c per kw-hr. Even in the above discussion many items have been omitted such as superintendence or the time that the $5000 manager applies to power house problems. The time and production lost due to breakdowns or late starts should also be

charged but these are items that have to be obtained in each individual case.

From the above consideration the effect of decreased hours of full load service together with the effect of load factor on the cost of power are clearly shown so it should be fairly clear that the central station which operates 24 hours per day can produce

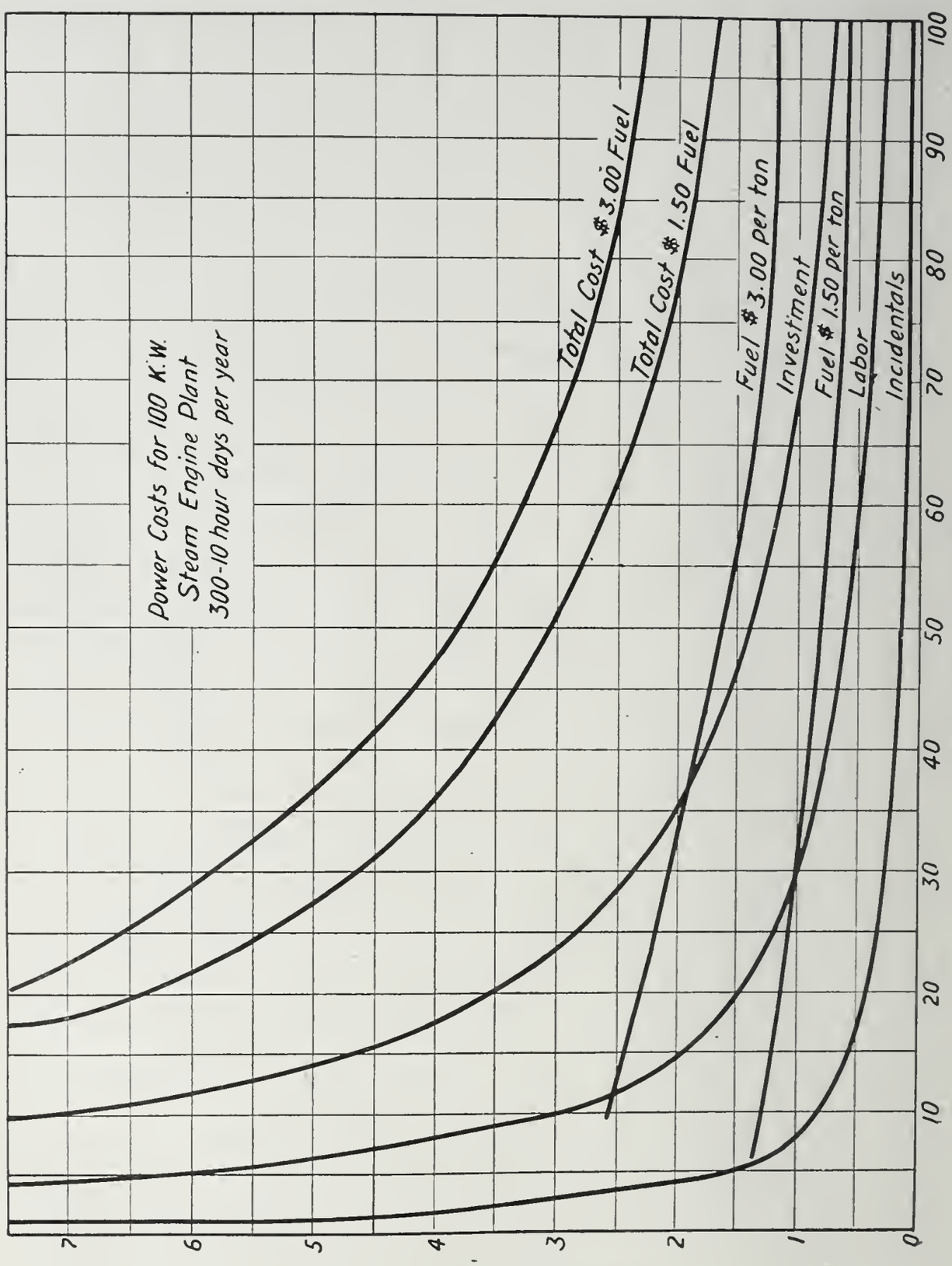

Fig. 4. Total Power Costs.

power cheaper than a private plant operating ten hours per day. The question of load factor affects the central station in just the same manner as private plants and in order to increase their load factor central stations make very low rates for off-peak loads. This load can be carried without additional equipment and investment charges so it is to the advantage of the consumer to avail himself of the low power rates during these times and by so doing still further raise the load factor on the central station and reduce the cost of power to all.

DISCUSSION

Mr. W. E. Reed: I made a few notes while Mr. Drake was reading his paper. One refers to the following comparisons of motors for group and indivudual drive:

Drive	Individual	Group	Individual / Group
Motors	11	1	11.
Rated H. P.	35.5	20.	1.7
Cost per H. P. in dollars	24.	15.	1.6
Total cost of motors in dollars	848.	297.	2.8

In this example of individual drive the motor h. p. is 1.7 times, the cost per h. p. is 1.6 times and the total motor costs are 2.8 times those for group drive. The motor investment is therefore considerably greater for individual drive. In choosing a drive the total cost of installation should be used instead of motor cost. The investment should include motors, starters, switches, controllers, wiring, foundations, line shafting, pulleys, hangers, belts and appurtenances installed and ready for successful operation. The comparative investments may then be quite different from the cost of motors with starters. This comparison will vary for different installations and should be figured for each particular case.

The operation and maintenance costs will also vary with each installation, but favor group drive when the machines are close together, when line shafting is fairly short and has low friction losses, and when power is cheap. They favor individual drive when contrary conditions exist; viz., when some machines

operate only part of the day and they may be easily and conveniently shut down with a saving in power consumed when not needed, when machines are some distance apart and there is considerable loss in the transmission line shafting which could be eliminated by individual motors and when cost of power is high. There are also cases where machines may be most economically driven by one motor for say three or four machines in a group.

The following data from an industrial works is a good example of conditions suitable for individual drive. A small steam engine drives three machines separated some distance from each other and considerable distance from the engine. All the shafting had to be operated when one machine was in use—data:

Machine	Feet of shafting	Feet of belting	Hangers	H.P. motor required	Average hrs. operation
No. 1	52	84	8	3	2
No. 2	42	30	7	3	5
No. 3	36	bevel gear	7	7½	6

A little consideration showed a large power saving by motor drive of individual machines.

The above is an exceptional case, however, and to choose the proper drive requires a detailed study of each installation considering complete investment, maintenance and operation, fixed and variable costs, and production. The increase in production by electric drive is generally of greater importance than the saving in power. In works where the power costs are five percent, a reduction of 40 percent in power consumed means two percent reduction in manufacturing costs. The increased output with electric drive is generally considerably greater than this amount.

In regard to rates, many contracts are based upon the h. p. of connected load because the actual maximum demand is not known before the transmission and distribution lines are installed. The only way of figuring the size and costs of these lines is therefore upon the h. p. connected. The maximum actual demand also changes after operations are begun and is not as definite as the maximum load the motors will carry.

The costs given by Mr. Drake are for alternating current motors. It would be interesting to know the cost of direct current motors and the difference in results if these prices were used.

The cost of power will change the results also and it would be valuable to know the difference in them if a 2c rate per kw-hr. were used.

I am entirely in accord with Mr. Drake's statement that few owners have even an approximate idea of their power costs or whether it is advisable to purchase or generate electricity. In many works the power plant and other expenses are not separated and costs can only be approximated until the bookkeeping methods are changed and new data is collected unless a complete test of the plant is made. Since central power plants have started an active campaign for day loads the importance of these costs have been forcibly brought to owners' attention.

The load factor may be based on 10 to 24 hours per day operation. For continuous operation it should be figured on 8760 hours per year basis.

In considering the purchase of power the necessity for steam in heating and manufacturing must be considered. Many works would require a boiler plant even if electric power was purchased. In this case the cost of electric current generation should be figured in conjunction with the necessary steam plant, considering them as a combined plant rather than separate installations.

Although large central power plants cost less per kw. than small plants they require additional investment and operating expense where competing with private plants. This additional cost is for transmission and distribution of current. Taking this into consideration there are many central power plants that cannot or will not compete with private plants. There are also many plants that pump water at a lower cost than they can purchase it. If actual figures were known, however, there would be many cases where power could be purchased to advantage.

THE AUTHOR: Mr. Reed mentions several interesting points which I had either over looked or intentionally neglected.

In the present case no allowance was made for erection of the motors since they are mounted on the floor or ceiling with no special foundations and four lag screws only are required for each motor. More time would probably be required for the erection of eleven motors than for one, but due to the lighter weight of the small motors, and the greater ease of handling the total cost of installing is not as great as might be expected.

The maintenance item for motors in planing mills and other service is so small that even assuming it were proportional to the number of motors it would still be of small account. Very few of these plants employ an electrician of mill-wright and there are many instances on record where the maintenance in plants having 15 or more motors is less than one percent of the investment.

The question of the maximum power demand is being looked into much more carefully now than formerly by central stations since, as Mr. Reed states, the central stations must be in a position to supply this demand at any time. The power rate makes use of this demand, as a basis, with certain other rates for the actual energy consumed. As I previously mentioned, this maximum demand should either be measured or carefully estimated, since if based solely on the horse power connected, it tends to discredit the use of individual motor drive by increasing the rate for any given plant.

There are many plants in which steam or hot water is required for manufacturing purposes, among them being paper mills, laundries, bleacheries, tanneries, etc. There are also many plants which have practically enough refuse to supply their fuel demand and also require steam, e. g. the dry kilns of planing mills and furniture factories. It might seem at first sight that central stations could not compete with a private plant under any of the above conditions. Perhaps in some cases if the central station is not well organized and equipped with modern machinery it may not be able to compete, but there are a multitude of planing mills using central station power and operating dry kilns by low pressure boilers, which have materially reduced their operating expense by so doing. The surplus refuse can be sold in many cases, although many times

it is simply given away to get rid of it. I know of some instances where the central stations have operated boilers on wood refuse allowing the manufacturer a price which paid a large part of the power bill. When central station power for some reason is not competitive a very good solution of the low pressure steam proposition has been found in the bleeder type turbine. By means of this type of turbine, which has been designed especially for this purpose it is possible to operate all of the boilers at 150 lbs. pressure and obtain practically any amount of steam at a low pressure, say three to ten lb., and at the same time utilize in the turbine all the power of the steam between the high and low pressure. The turbine automatically maintains the desired low pressure and any steam not required by the low pressure system passes on through the low pressure part of the turbine to the condenser so that a very low water rate for the turbine is obtained. Such equipments are admirable for paper mills, laundries, etc., where large volumes of steam are required for drying and water-heating and there is also a large electrical load to be carried. In case no low pressure steam is required at times the turbine operates with the same efficiency as a standard condensing outfit.

Mr. W. E. Reed: There was another question about the relative costs of direct and alternating current motors and how results would be changed for direct motors.

The Author: I can not say off-hand what the relative cost of alternating and direct current motors for this installation would be. Perhaps Mr. Popcke can give us some information on this.

Mr. A. G. Popcke: The relative cost for ratings generally used is in the ratio of about 28 for induction motors to 30 for *DC* motors, considering motors complete with starters, pulley and sliding base for belt tightening.

The Author: The cost then would be about seven percent higher for the direct current than for the alternating current motors. For the same voltage a three phase circuit would take only 75 percent as much copper as a direct current circuit, but the additional labor of installing same in a building would

probably nearly off-set this saving in small installations. For alternating current a voltage of 440 or 550 is often used, which would effect quite a saving in the cost of wiring over 220 volts direct current.

A MEMBER: What of the cost of gas engine power?

THE AUTHOR: The gas engine is used quite extensively in the Pittsburgh district, due principally to the cheap natural gas and from the tests which I have seen I believe that the actual fuel consumption per horse power is very low. Fuel cost is, however, only one item and others to be considered are the fixed charges of interest and depreciation together with the maintenance. Small gas engines are rapidly being replaced by central station power and the principal reason in most cases is the unreliability of the engine. A late start or a shut-down now and then costs more than the fuel for many weeks, and reliability of service, together with the unlimited supply and availability at any time are the items which are possessed by the central stations and not by the gas engine. Gas engines in the larger sizes are much more reliable and when operated by high class engineers give satisfactory service. I know of several instances in which the total power cost considering both the fixed and variable charges is lower than that offered by most central stations. I have in mind a 500 h. p. gas engine, which is operating very satisfactorily, 24 hours per day, six days per week. Due to the scarcity at times of natural gas it is now necessary either to install a gas producer for the engine or use central station service. The owner stated he would willingly pay ten percent more for central station power and be entirely free from the care and worry attendant with the use of an engine and producer. There are a lot of items which really should figure in the power cost, but which are difficult to figure in dollars and cents and the above statement is simply an acknowledgement of this by a present gas engine owner. I should be glad to hear from some of the gas engine users present tonight.

MR. A. STUCKI: I am convinced that the gas engine is as reliable as the steam engine. I have known cases where they have run seven, eight and nine years in succession and about

all the attention they get is a few minutes now and then from a man who works at a bench, but the secret is, that he understands the engines. Then again I know of gas engines of exactly the same make, size and workmanship which broke down continually and caused nothing but trouble, and had it not been for an extra steam engine the shop would have been in a bad fix. The manufacturer was often called in to remedy the trouble and he overhauled the vital parts, but with no success, until some time ago the attendant was changed. Since then the engine has run without the slightest interruption.

Regarding the relative cost of power, Mr. Drake mentioned $150 for small plants and $60 for large ones. In the latter case you mentioned 1.2 cents per kw. hour being an average selling price. It would be interesting to know just how cheaply you can manufacture in a large power plant.

Another point is this. It struck me that Fig. 2 shows proportionately too much in favor of the individual drive, the cost only being about half of that in a group drive. This is more or less an optical delusion and would at once disappear, if the actual work done in each case would be added.

One point decidedly in favor of a group drive has not been brought out. Leaving aside planing mills or flour mills, the two extreme cases, and confining ourselves to manufacturing plants and foundries, we have often found it advantageous and economical to group machines of a similar nature together on short shafts. This makes the first installation less expensive, enables us to use fewer units, but what I especially want to bring out is that it enables us to get along with a few sizes. This in turn reduces the number of repair parts which have to be kept in stock to meet emergencies.

The swing grinders connected directly to the motor as shown on the screen, must require a great deal of floor space. Will they compensate for this in other ways? We had swinging grinders which did not take up half the room and were entirely satisfactory.

I would also like to come back to the question of covering motors in cement and planing mills. In some plants I know good results are being obtained by covering the motors top,

bottom and two sides, and at the same time there are many places where the motors run open and give entire satisfaction. Is it a mistake to box them on top, bottom and two sides?

Electric experts always told me to blow the motors out periodically and the oftener the better, alternating as well as direct current motors. It was also urged, that a man be given charge over the motors, to watch them constantly and not only once in a while, and as far as my experience goes, this expense is fully justified.

THE AUTHOR: The figures of $60 and $150 per kw. mentioned in the paper are the investment costs per kw. for large and small stations and cover the entire equipment. As the size of the power house increases the cost per kw. decreases. The actual cost of manufacturing power in large central stations depends upon many conditions: as location, fuel, type of transmission systems, etc. In a large city where all of the conductors are underground, where a large office force is necessary and rentals are high the cost per kw-hr. is as high as 2c, while many smaller plants are able to generate power as low as ¾c including all over-head and transmission losses.

I notice Mr. Stucki favors group drive, principally on account of the reduction in the number of motors and repair parts necessary to carry for them. The selection of group or individual drive must be determined by the local conditions and depends primarily on the size of the machines and their method of operation. When installing a new plant, I believe in most cases the cost of individual drive will not exceed the cost of group drive including all of the shafting and belts and the operation afterwards will be much more economical.

In regard to covering motors, I would state that on the induction motor the only parts injured by dirt are the bearings and these are easily made dust-proof by means of felt and steel washers. These dustproof covers effectively keep out the dirt so that the motors will satisfactorily operate in the thickest cement dust. Shavings and saw-dust do not have an injurious effect on the bearings and for most cases dustproof bearings are not required in planing mill service. It is unnecessary to box

the motors to keep out dirt and if the service required of the motors is fairly constant the box becomes actually harmful by increasing the temperature of the motor. It is well to blow out motors occasionally, since the collection of dust on the iron and windings tends to prevent the circulation of air and increases the temperature. In some cement plants compressed air is piped through the building with taps at convenient intervals. Moisture, water and chemicals are much more injurious than dirt and motors should be protected from the direct action of any of these.

The Hassel swinging grinder referred to is easily moved from one casting to another so that the floor space is very well utilized. The castings being heavy much time can be saved by moving the grinder over the castings instead of bringing the work to the grinder. What kind of a swinging grinder did you have in mind?

Mr. A. Stucki: The ordinary swinging grinder.

The Author: For light work the ordinary swinging grinder may be entirely satisfactory but even then the Hassel grinder will do the same work in the same manner and eliminate several bearings and troublesome belts. There is also a considerable saving in power and one of the greatest advantages is the uniform grinding speed and ability to operate the grinder at maximum safe speed at all times.

Mr. A. Stucki: I noticed in the view on the screen that you were grinding bolsters. We pile them up and put one or two in position, using only a space of say 6 by 10 ft., while you use a great big floor space and still you cannot grind any more than one at the time.

Mr. E. K. Hiles: Have any measurements been made of the power saved in driving wood working machinery, saws and planers especially, by direct connected motors instead of belted motors?

The Author: Circular saws are very readily driven by direct connected motors, since they run at high speed and in

many cases motors at 1700 or 3400 r.p.m. are used. Much greater production is obtained with a smaller power consumption when using the coupled drive, due principally to the better speed regulation. With a belt driven saw the belt slips as the load comes on, and after the speed of the saw is reduced two or three hundred revolutions, its operation is very unsatisfactory and an excessive amount of power is required to cut the wood. For saw mill work, lath mills especially, coupled motors, at 3400 r.p.m. have been found very satisfactory. For the larger saws, motors at 1700, 1120 and 850 r.p.m. are used, the actual speed depending on the diameter of the saw and the limiting speed being about 10 000 ft. per minute.

Probably a larger saving could be effected by using coupled motors on planers and matchers, but at the present time most of these cutting arbors operate from 4000 to 5000 r.p.m. and these speeds cannot be obtained with induction motors. By building larger cutting heads the same cutting speed at 3400 r.p.m. could be obtained and I understand that some wood-working machinery builders are now re-designing some of their machines with a view of using direct connected motors for driving them. A large planer and matcher with four heads would have a friction-load varying from 15 to 20 h. p. and most of this is caused by the four tight belts and the countershaft. Since two of the heads on this type of machine are vertical and within the machine it is doubtful if direct connected motors are used for the vertical heads for some time. With direct connected motors on single and double surfacers from 50 to 75 percent of the friction load would be eliminated and a much more uniform cutting speed would be obtained due to the elimination of the belt slip.

The various wood-working machinery companies are becoming much interested in motor driven machines and are co-operating with the electrical companies. At the present time several types of coupled saws have been placed on the market and I believe within a short time direct connected planers and jointers will be available.

Mr. A. G. Popcke:* Tests were recently made in a steam engine driven machine shop to determine the size of electric motors to be used to drive it in groups. The results obtained given some interesting data with which individual and group drive can be compared.

A Westinghouse graphic recording meter was used to make these tests. This method is the most accurate and gives the most useful results for commercial work of this nature, because the power consumed at every instant is recorded over any desired period of time. This method of investigation applied to machine shops is described in detail in the Transactions of the American Society Mechanical Engineers in a paper by Mr. Chas. Robbins on the "Economical Features of Electric Motor Applications" read in April 1910.

Some of the results of the tests made in the machine shop mentioned are summarized in Table No. 1.

This table shows that there is one kilowatt friction loss of overhead work (main shafting; counter shafting and belts) for an average of about 30 ft. of main shafting. The no load friction loss per machine, i. e. the total no load friction divided by the number of machines connected, averages about 200 watts or the equivalent of about four 16 c. p. carbon filament lamps or on a more modern basis the equivalent of five 40 watt tungsten lamps or 160 c. p. A shop superintendent passing through his shop, detecting a 16 c. p. lamp lit in bright day light gives the operator a calling down. He does not realize that the overhead shafting and belting for each machine is consuming as much energy as four such lamps. Moreover, what a brilliant lighted shop half the consumption of this wasted energy could make!

The fundamental question for an engineer or shop manager to solve in making any changes in an equipment can be stated as follows: How shall I invest money in order to obtain the greatest returns upon the investment?

*Electrical Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh.

Floor No. (See note for type of machines)	1	2	3	4	5	6
No. of Machine Tools	85	71	52	97	136	183
Feet of Main Shafting	417	617	233	528	796	760
No load Friction Loss —kw.	16.5	20	9	19	26	31
Average Load—kw.	27	36	24	41	48	93.5
Percent $\frac{\text{Friction Loss}}{\text{Average Load}}$	61	55.5	37.5	46.4	54	33
Feet of Main Shafting per kw. friction loss	25	31	26	28	31	25
Friction loss per machine tool—kw.	0.195	0.280	0.173	0.195	0.190	0.170
Average load per machine tool—kw.	0.318	0.51	0.46	0.42	0.35	0.51

Note: In the above the speed of main shafting is from 180 to 200 r.p.m.; there is a self oiling bearing every eight feet, a coupling every 16 feet. The hangers are mounted upon eye-beams. The overhead work is kept in good condition, being thoroughly lined up once a year. The counter shafts are examined and oiled once a month.

The following is a list of machines connected to the shafting on the various floors:

Floor 1. 37 Lathes, 10 to 20 in.; 21 Milling machines: 19 Drills, 12 to 24 in.; 7 Radial drills, 4 to 5 ft.; 1 Grinder.

Floor 2. 46 Grinders, buffers and polishers; 15 P. & J. automatic turret lathes; 10 Miscellaneous machines as small lathes, drills, slotters and tool grinders.

Floor 3. 20 Lathes, 12 to 20 in. (moderate duty); 13 Vertical boring mills, 30 to 48 in.; 6 Drills, 12 to 24 in.; 4 Heavy vertical boring mills, 60 to 90 in.; 3 Small planers; 3 Milling machines; 2 Tool grinders; 1 Radial drill, 6 ft.

Floor 4. 42 Lathes, 12 to 24 in.; 33 Milling Machines; 10 Radial drills, 4 to 6 ft.; 5 Small drills; 5 Horizontal boring mills; 2 Tool grinders.

Floor 5. 81 Lathes, 12 to 36 in.; 32 Milling machines; 5 Small planers; 13 Drills, 10 to 24 in.; 3 Radial drills, 4 to 6 ft.; 2 Horizontal boring mills.

Floor 6. 110 Automatic gear millers; 32 Automatic gear planers; 41 Lathes, 10 to 20 in.

Table No. 1. Anaylsis of Power Consumption in a Machine Shop.

With the results of tests given in Table No. 1 and the cost of putting up shafting and belting and the cost of installing motors, calculations can be made to determine which is the better investment—group drive or individual drive. The following is a calculation of this kind for floor No. 5 referred to in Table No. 1.

GROUP DRIVE—COST OF INSTALLATION.

MAIN SHAFTING:

796 ft. 2-15/16 in. Shafting @.523		$418.00
Keyways for Cplgs. .374x100		37.00
100 hangers (25 in. drop)		1055.00
50 Couplings @ $7.44		372.00
3 Clutches		345.00
Labor to put up (14c. per ft.)		112.00
		2339.00
Cost per ft. of main shaft	$2.90	
Feet per Machine, 5.9		
No. of Machines, 136		
Cost per Machine	$17.20	

COUNTER SHAFTING:

136x$30	$4080.00
Labor 2.50x136	340.00
Belts (55 ft. Mach. Av. Wid. 3 in. Single) 136x55x.13	970.00
Pulleys on Main Shaft (10 in. Aver.) 2x136x$2.00	544.00
	5934.00

MOTOR:

50 h.p. @ 850 r.p.m.	450.00

SUMMARY OF COSTS:

		% of Total
Main shaft	$2339.00	27
C. S. & Pulleys	4964.00	57
Belts	970.00	11
Motor	450.00	5
	$8723.00	100

GROUP DRIVE—COST OF POWER FOR FRICTION LOSS:

Total no load friction loss—26 kw. at 2 cents per kw.-hr. and 2808 hrs. per year, the cost is $1460 per year.

The loss increases with load approximately 70 percent.

The cost of full load friction is $2480 per year.

Cost of Individual Drive.

On the average a 2-h.p. 1120 r.p.m. motor will be required to operate each of the machine tools in the above group.

Cost per motor if A. C. is used $64 net.

Total cost 136 machines—136x64=$8700.

Add 20 percent for wiring, extra attachments, etc. $10500.

Friction Loss of Individual Drive

No load loss of all machines running light is 136x.20=27.2 kw. But the time factor based on working hours for machines of this type is 25 percent, therefore.

Average load=.25x27.2=6.8 kw.

Cost per year=2808x.02x6.8=$382 per year.

The full load losses of the motor can be estimated at 80 percent increase over no load losses. These are therefore 1.80x382=$690 per year.

Difference in First Costs

Individual drive,	$10500
Group Drive	8723
Difference	$ 1777

Difference in Friction Losses, based on no load friction.

Group Drive	$2480 per year
Individual Drive	690 " "
Difference	$1790 " "

Time to pay for difference in first cost based on money saved in friction loss.

Based on no load friction

$$\frac{1777}{1078} = 1.65 \text{ years.}$$

Based on full load friction

$$\frac{1777}{1790} = .99 \text{ years.}$$

This shows that the difference in first cost will be paid for in two years if the difference in friction loss alone is considered

at two cents per kw.-hr. The friction loss in large shops is one of the items of least importance of the operating expenses, since the total power consumed is usually only one or two percent of the total operating expenses.

If the cost of installing individual motors is 50 percent of their purchasing cost instead of 20 percent as above assumed, the difference in first cost would be $4277 and difference in cost of friction (average between full and no load) $1439 and the difference would be paid for in

$$\frac{4277}{1439} = 3 \text{ years.}$$

Table No. 2 gives the results of a similar analysis of costs for the remaining floors referred to in Table No. 1.

These figures show that if the proper motor is used for individual drive, the difference between the cost of individual and group drive is not very large if a new shop installation is considered, and will be paid for in two years—average. Instead of investing money in shafting and belting, it can be more economically invested in the purchase of electric motors for individual drive. It must be remembered that the condition of the overhead work upon which these results have been based is ideal compared with that of the average machine shop where line shafting is more or less out of alignment, bearings and counter shafts are loose and belting covered with oil. In these cases the friction losses are greater and the individual motors would show still greater advantage. With higher cost of power the advantage is also greater.

In cases where an old shop is completely equipped with line shaft drive it naturally would not pay to scrap all the overhead work already installed at once, but whenever new machine tools are purchased, or whenever changes are made in a shop layout the problem should be investigated in a manner similar to that above outlined to determine the advantages of each type of drive from an economic point of view; in the majority of cases individual drive will show the greatest number of advantages.

Floor Number	1	2	3	4	5	6
No. of Machines	85	71	52	97	136	183
Feet of Main Shafting ..	417	617	233	528	796	760
Group Drive						
Cost of installation of:						
Main Shafting	$1495	$1674	$ 692	$1315	$2339	$ 2240
Counter Shafting & Pulleys	3102	2592	2030	2541	4964	6680
Belts	607	510	745	694	970	1310
Motors	317	1323	386	416	450	1222
Total	$5521	$6099	$3853	$4966	$8723	$11452
Cost of friction load per year:						
Based on no load losses	$ 930	$1125	$ 507	$1070	$1460	$ 1740
Based on full load ...	$1580	$1900	$ 865	$1820	$2480	$ 2960
Individual Drive						
Average H.P. of motor	2	3	3	2	2	3
Cost of motors plus 20%	$6550	$6360	$4750	$7500	$10500	$16800
Cost of friction load:						
No load	$ 240	$ 220	$ 161	$ 273	$ 382	$ 562
Full load	430	396	290	490	690	1010
Difference between costs of group and individual drives.						
First Cost	$1029	$ 261	$ 897	$2534	$1777	$ 5348
Friction load:						
Based on no load friction	$ 690	$ 905	$ 346	$ 797	$1078	$ 1178
Based on full load friction	$1150	$1504	$ 575	$1330	$1790	$ 1950
Time to pay for difference in years:						
Based on no load friction	1.5	0.29	2.6	3.2	1.65	4.5
Based on full load friction	0.9	0.17	1.6	1.9	0.99	2.7

(Note:—Cost of power based on 2c per kw.-hr.)

Table No. 2. Analysis of First Cost and Cost of Friction Loss in Group Driven and Individual Driven Machine Shops.

BUILT UP ROOFS

By W. S. Babcock.

The term gravel or slag roof applies to composition roofs of coal tar pitch and coal tar felt or asphalt saturated felt and asphaltic cement, finished with a covering of gravel or slag.

Owing to the similar appearance of the materials, the terms "Asphalt" and "Pitch" in roofing specifications are often confused. As a matter of fact the general term is "Pitch", and it includes all substances of that nature from whatever source, the dictionary definition of asphalt being "mineral pitch". Therefore, while all asphalt may be called pitch, all pitch cannot be termed asphalt. Of the kinds of asphalt pitch, or more briefly, asphalt, that can be used for waterproofing, there are barely four or five out of fifty or more varieties that are in any respect suitable for such purposes. Of the other kinds of pitch there is only one—coal tar pitch—that can be considered for such work.

As between the two, engineers and architects who have taken the time to investigate their relative waterproofing qualities are practically of one opinion, that coal tar pitch is far better than any asphalt. Evidence as to the correctness of this statement is being constantly furnished from old buildings where coal tar pitch has been in use twenty and thirty years and yet is chemically, mechanically and in other respects in exactly the same condition as when first applied.

Information concerning the relative value of the bituminous materials for roofing is not easily available. The detailed knowledge held by the leading concerns preparing the materials has been acquired by expensive experience and is regarded as a valuable asset not to be shared by possible competitors and the

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ignorant purchaser. Those supposed to be expert in the matter, the manufacturers and engineers, differ widely in their statements as to essential details.

ASPHALT

The term asphalt is ordinarily considered as referring to bitumens found naturally in the solid state and will be so used in this paper. These are obtained all over the world with widely varying qualities. Mention will be made of those most important commercially in this country.

The asphalts are generally stable in the atmosphere. As found naturally, they are not commercially available, even after the impurities are removed, being too hard and brittle for most purposes. This is ordinarily remedied by softening or fluxing with various oils, an operation requiring skill, however, there seems to be no set rule for fluxing. The character of the fluxes has a most important effect upon the finished product. Petroleum products are ordinarily depended on for this purpose. The fluxes should be sufficiently stable to insure against too rapid hardening of the fluxed asphalt. They should be free from deleterious constituents and should be of such a character that they will combine with the asphalt to be fluxed so as to make a homegeneous and perfect solution. Certain fluxes which work well with certain asphalts are not at all suitable for use with other asphalts. Poor results are sometimes supposed to be due either to chemical action in the fluxes or to chemical action between the fluxes and the asphalts. Tars are sometimes employed for fluxing purposes, but they do not mix easily with asphalt. As asphaltic compounds age they tend to become brittle and hard, losing their elasticity and binding power. Poor fluxing hastens this process.

Commercial refined asphalts, intelligently and honestly refined, should and do run very uniform. When they are compounded, however, brand names have very little significance and less value, and should not be taken in themselves as indicative of the character or value of the compound. Some types of asphaltic compounds properly prepared and used have quali-

ties which make them almost indispensable for some classes of roofing.

The asphalt which has been most widely exploited in the United States is that which comes from the island of Trinidad. This occurs in a large deposit and has the valuable feature of being unusually uniform in quality. As mined it contains large percentages of water and of mineral matter in a finely divided state. There are also some soluble salts present in small quantity which possibly may help to explain the fact that it is acted upon by standing water, and is not suitable for use in underground waterproofing and at points where it does not have a chance to dry out. This is not so serious a defect in a street pavement where the surface coating is made dense and where the pavement is covered by water for short periods only, although where depressions collect standing water deterioration soon results. Sunlight affects it somewhat but it is not volatile in the atmosphere. Perhaps thirty percent may be considered as a fair average of the amount of flux necessary to add to it for the preparation of an asphaltic roofing cement. To prepare it for use the water and what vegetable matter may be present are removed. Over a third of the refined product is mineral matter.

Bermudez asphalt comes from Venezuela, is not quite so uniform as the Trinidad and is softer than the other widely known commercial solid asphalts. It contains but little mineral matter, but otherwise possesses many characteristics similar to those of the Trinidad.

In Colorado and Utah occur gilsonite and elaterite which have some characteristics in common and which are often nearly pure bitumens. Gilsonite is hard and brittle, requiring considerable quantities of flux to make it available for use. It is not always uniform in its qualities. It is to some extent exported and is used for varnish. It is claimed as the base of many of the asphalt roofings but is not a good saturant. Elaterite is more expensive, is softer than gilsonite and is not found in such large quantities. Some manufacturers of roofing claim to use it. We have not heard of its having any special superiority.

Grahamite or "Choctaw" which comes from Oklahoma is not much used for roofing. It does not dissolve readily in the

ordinary fluxes and in its physical characteristics is more like soft coal.

Southern California has deposits of asphalt of excellent quality but their cost of mining and the excellent character of the California oil residuals has driven them out of use. When California asphalt is mentioned the oil residuals are ordinarily referred to.

Rock Asphalt or Mastic Rock: Sandstone saturated with bitumen is found naturally in various places in the country, principally in California. It is sometimes known as mastic rock, and is more valuable for paving and floors than for roofing or waterproofing, where it is rarely used.

Maltha: Maltha, in this country found mainly in California, is a semi-liquid asphalt containing light oils which tend to evaporate upon exposure to the atmosphere leaving what is practically an asphalt. It grades into the California petroleum and the deposits are not extensive enough to be of importance commercially. There are underground deposits of this material so heavy that they cannot be pumped, and for which no practical scheme of extraction has been devised.

Petroleum Residuals: The petroleums found in the United States vary in quality according to their location. Hubbard divides the important deposits into six fields.

TARS

Coal Tar: From the distillation of bituminous coal, either in a plant for the production of illuminating gas or in a by-product coke oven the products may be roughly divided into four classes: the gas; the ammoniacal liquor which is the scrubbing water with the materials which it has absorbed from the distillates and which it holds in solution; the coal tar; and a heavy liquid containing the distillates insoluble in water which have settled away from the ammoniacal liquor and the coke.

The coal tar contains some water, various impurities and free carbon which after the water has been removed, is ordinarily from five to thirty-five percent of the total. This is carbon formed by the cracking of the hydrocarbons and is in a very finely divided condition. The percentage varies with the

method of manufacture. The distillates or bitumen are composed of hydrocarbons which have widely varying melting points and degrees of volatility. These may be roughly classified into light oils, creosotes and pitches. The character of the tar varies with the coal used and the manner in which the process is carried on. The tar from each plant has its individual characteristics. The greater the heat, the more the hydrocarbons are cracked into their constituents and the greater the amount of free carbon and of gas found and the less the amount of coal-tar. By carrying the process to its theoretical limit the final products of distillation would be gas and carbon.

The question of the relation between free carbon and coal tar is one of considerable importance. It is generally considered to be a valuable adjunct to roofing tars and pitches. Free carbon makes the material less affected by changes in temperature. Comparing two pitches of similar consistency at normal temperatures the one having the greater amount of free carbon must have, to neutralize it, a greater percent of the lighter, more elastic and to some extent more volatile hydrocarbons and less of the heavy pitches. When the pitch is cold it is less brittle and when it is hot it does not flow so readily because of the carbon present. Thus a tar of a given consistency may, notwithstanding the fact that it contains large quantities of an inert material, apparently have more life than another with less of the free carbon.

To determine the probable action of any tar or pitch under different temperatures its percentage of free carbon must be known as well as its melting point. The free carbon does not interfere with the saturating power in felt although it is liable to be largely deposited on the surface of the felt.

When coal-tar pitch is exposed to the weather there is found upon its surface a thin layer, hard and brittle, the residue after the drying out of the volatile oils. This acts as a sort of protective coating to what is underneath. As soon as it is disturbed, exposing fresh pitch, the process is repeated. High carbon tars seem to weather better than low carbon tars, the increased amounts of free carbon seeming to aid in the foundation of the skin or protective coating.

The amount of free carbon in the commercial product is often regulated by combining coke oven tar, which because of the design of the stills is low in free carbon, with gashouse tar. The coke oven processes where much attention is given to the by-products can be made very uniform. It cannot be said that gashouse coal-tar is better than by-product oven tar or vice versa.

The statement frequently made that tar roofing material suffers in quality because it has been robbed of constituents desired in the manufacture of chemicals is not true. The lighter constituents are distilled off to leave a pitch of a certain desired consistency. In this process air or steam is frequently blown into the still. This prevents the deposit of free carbon on the sides and bottoms of the still and to some extent aids the escape of lighter oils which would otherwise be held in solution. These oils if present in the pitch would tend to gradually evaporate, making the pitch unstable. The other way to remove them is to use heat where danger of damaging the tar exists.

Watergas Tar: Watergas is made by passing steam over hot coke or anthracite coal, which, decomposing the steam, forms carbon monoxide and hydrogen. This does not possess sufficient illuminating power, and to enrich it, there is added a gas produced from petroleum which leaves a tar often used in place of coal-tar. In the process which it undergoes the oil residues are so changed by the high heat as to lose many of their characteristics and to acquire some of those of the compounds found in coal-tar. Compared with coal-tar, its oils have less antiseptic properties. As obtained from the gas manufacturers it is thinner, containing more water, more light oils and less of the pitches and no free carbon. It is distilled down and treated much as is coal-tar and its pitch is very similar in appearance to that of coal-tar.

Watergas tar decomposes easier than coal-tar. It often contains some paraffine though ordinarily not in sufficient quantities to affect the product. The crude watergas tar is also much more affected by water and is capable to a considerable extent of forming an emulsion with it. Good coal-tar is practically unaffected by water, and it deteriorates from the surface only.

Oil tar products like the oil fluxes used with asphalts are liable to undergo chemical changes which may tend to make the entire mass hard and brittle.

Watergas is now made practically everywhere and ordinarily mixed with coal gas. In one large plant from the same amounts of gas, the watergas produces about a third of the amount of tar that coal gas does. The coal gas, considering its by-products, is under favorable conditions the cheaper, but the watergas requires less of a plant and allows greater flexibility of operation. The prices of materials and the demand for coke affect the relative outputs. In the large plant previously spoken of the proportions of coal and watergas made vary between two and three of watergas to one of coal gas.

In the larger illuminating gas plants the two sorts of tar are generally separated, but in many of the smaller plants they are mixed together. There is no reason why they should not be kept separate except for the cost of separate receptacles. In this country, the by-product oven and gas tars, both coal-tar and watergas, are bought by a comparatively limited number of concerns who closely guard their processes. They compound the different sorts possessing varying characteristics, endeavoring as far as possible with their supply and their desire for maximum profits to meet the needs and demands of the consumer. The consumer in his ignorance does not know what he is getting and probably usually does not know what he needs. The detection of oil-tar in coal-tar products is a difficult and uncertain matter, especially when it is under twenty-five percent of the total. We are not sure that it has been proven that a reasonable amount of watergas tar seriously injures a coal tar for roofing purposes, especially when used as a saturant, although it is generally in disfavor.

Not long since practically the only use of tar was for roofing and the entire supply came from the manufacture of illuminating gas from coal. The situation has been changed by the increasing supply from by-product ovens, by the manufacture of watergas in large quantities, by the great demand for creosote oils and other by-products, by the use of coal tar for waterproofing masonry, by its use for briquetting coal slack and by

its adoption for use as a road binder as a protection against the ravages of the automobile. We would sum up the remarks on the bituminous materials as follows:

With skill in compounding, based on a thorough working knowledge of the materials used, asphaltic compounds can be prepared of natural asphalts and oil residuals, with valuable qualities for many different roofing needs, whose durability under known conditions can be foretold with considerable ascuracy. The same can be said, perhaps with more certainty as to results, of the different tars. Either can suffer from adulteration and poor preparation. Considering first-class materials the coal-tar pitch is cheaper, more easily affected by temperature changes, and is not acted upon by water nor is it liable to internal chemical changes.

From these compounds the only definite information that can be furnished by laboratory tests as to probable life and weathering properties is negative in its nature and quite inconclusive. Specifications to be enforced must include factory inspection and knowledge of materials used.

FELTS

The felts used with almost all bituminous roofings play a very essential part in the final product.

The desirable qualities of the felt vary with the waterproofing material to be used. In using asphalt, absorbent power is the main thing desired. In using coal-tar pitch (which under heat is made more liquid) this quality is not so necessary. All felts must be strong enough to avoid damage in handling before combining with waterproofing material. The strength of the finished product is due to a great extent to the complete union of felt and waterproofing compound.

The felts are mainly made of rag stock which is chiefly cotton rags. Notwithstanding the statements of many manufacturers, all-wool felt is never used for roofing, because of its expense and because it would be too soft and tender to work. A certain proportion of wool rags helps to make a felt which is open and spongy with considerable saturating power. The best felts for saturation rarely contain more than 25 to 35 per-

cent of wool. As ordinarily used the term wool-felt applies to a soft open felt with very little wool in it.

Sometimes paper stock, which is ordinarily wood pulp, though it may contain an appreciable percentage of straw, is used in small quantities if the felt is getting too soft. It has practically no saturating power but it can add to the cheapness of the material. If used in any proportion over two or three percent it is an adulterant to cheapen the product when it is made to sell to roofing manufacturers.

The felt materials ordinarily come to the factory in large bales already sorted with fair accuracy and are bought according to different grades. These are used together in varying proportions to get different results and to meet variations in the materials. But little sorting is done at the plant except to watch for specially undesirable constituents.

The methods of manufacture have a considerable effect on the quality of the material. The felt must be well beaten to avoid large lumps which are sources of weakness. The felt is made on a machine similar to that used for making ordinary paper and variations in its operation determine the quality of the finished product.

The dry felts are sold by weight. The standard is the amount which would lay 480 sq. ft. If a felt weighs 28 lb. to 480 sq. ft., it is known as No. 28. For this reason felts sometimes have their weight increased by the addition of a mineral filler. This is nothing more than an adulterant which interferes with the saturating power. Some specifications which require a certain weight of felt get around such adulteration by requiring that the ash in the unsaturated felt must not exceed 5 percent.

Felts of asbestos are used in one or two roofings. These are poor saturants.

Jute woven in the form of burlap or canvas is used in some roofings to add strength. Its value is debatable. It is not a saturant like the felts and its fibres are not so thoroughly protected, making it liable on exposure to rot or fire.

BUILT-UP ROOFS

The main use of tar for roofing has been in the construction of built-up roofs where layers of felt saturated with tar are nailed down and by the use of a coal-tar pitch protected and cemented together.

For the method of applying roofs, I know of no better form than the one referred to by the Committee on Buildings, of the American Railway Engineering & Maintenance of Way Association.

The following specification accompanied by the necessary diagrams give what is considered as good practice in the construction of a flat built-up roof on wooden sheathing:

ROOFING: First: Lay one thickness of sheathing paper, or unsaturated felt, weighing not less than five pounds per 100 sq. ft., lapping the sheets at least one inch.

Second: Lay two plies of tarred felt, weighing 14 to 16 lb. per 100 sq. ft., lapping each sheet 17 in. over the preceding one, and nail as often as is necessary to hold in place until remaining felt is laid.

Third: Coat the entire surface uniformly with straight run, coal tar pitch.

Fourth: Lay three plies of tarred felt, lapping each sheet 22 in. over the preceding one, mopping the pitch the full 22 in. on each sheet, so that in no place shall felt touch felt. Such nailing as is necessary shall be done so that all nails will be covered by not less than two plies of felt.

Fifth: Spread over the entire surface a uniform coating of pitch, into which, while hot, embed not less than 400 lb. of gravel, or 300 lb. of slag to each 100 sq. ft. The gravel or slag shall be from ¼ to ⅝ inch in size, dry and free from dirt.

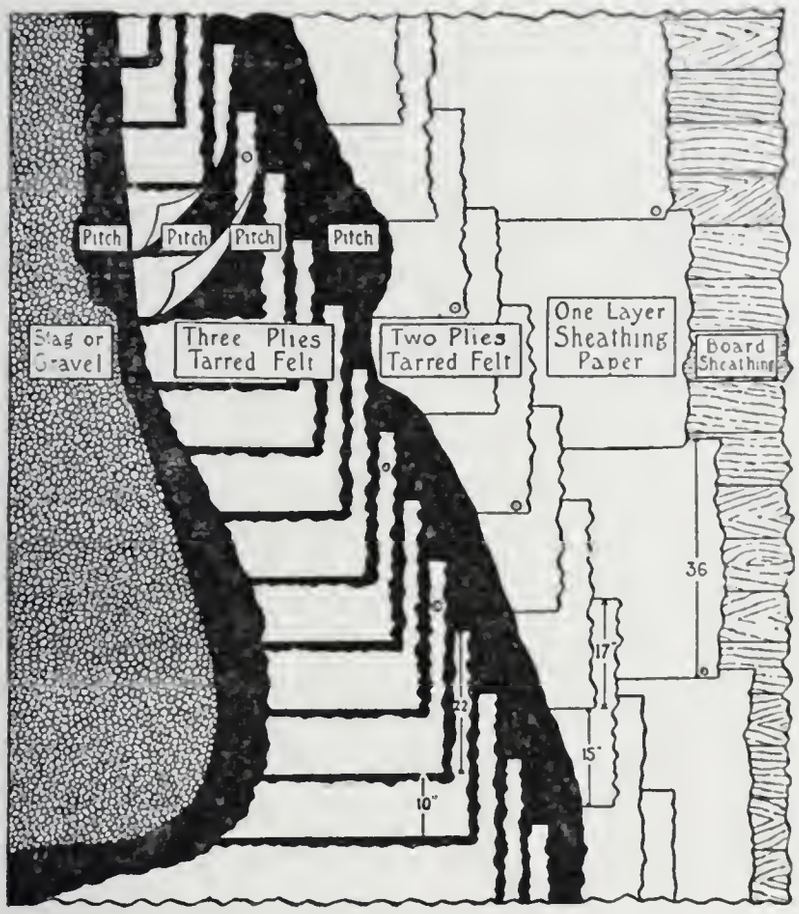
FLASHINGS: Flashings shall be constructed as shown in detailed drawings.

INSPECTION: The roof may be inspected before the gravel or slag is applied by cutting a slit not less than three feet long at right angles to the way the felt is laid. All felt and pitch shall bear the manufacturers labels.

To comply with the above specification, the materials necessary for each 100 sq. ft. of roof are approximately as follows: 100 sq. ft. sheathing paper, 80 to 90 lb. tarred felt, 120 to 160 lb. straight run, coal tar pitch, 400 lb. gravel or 300 lb. slag.

In estimating felt, the average weight is practically about 15 lb. per 100 sq. ft. and about ten percent extra is required for laps.

In estimating pitch, the weather conditions and expertness of the workmen will effect the amount necessary for the moppings, and to properly bed the gravel or slag.



The sheathing paper or unsaturated felt is placed on the bottom next to the roof boards, mainly to keep any pitch which might penetrate the two-ply felt above it from cementing the roofing to the sheathing. It also is of value in preventing the drying out of the roof through open joints from below. The saturated felts should be nailed where there is any chance of disturbance of the roof from underneath by the wind and also enough to hold it in place while laying. The practice in regard to nailing varies in different parts of the country, but the fewer nails, the better, so long as the roof is held in place.

The two layers of saturated felt first laid are necessary in order to carry and give full value to the amount of pitch which must be handled in one mopping. One of the troubles with

built-up roofing as ordinarily laid is the difficulty in getting thorough moppings between the felt layers.

For a concrete roof, when incline does not exceed one inch in one foot, nailing is not necessary and the practice is similar except that a dry sheet is not necessary, the concrete being first coated with pitch and the first two layers are mopped the full 17 in. Special care should be taken in regard to flashing and to prevent the roofing from being loosened at the edges either by wind or fire. Most leaks occur around flashings and openings.

The felts are saturated with heated tar about as it comes from the gas-house with the water and other impurities removed. Oil-tar with its liquid qualities is said to be much used for this purpose. This is more permissible than it would be if the felt were to be exposed.

After the original two layers of saturated felt are used, the additional layers are merely to give additional thickness of wearing material, and with a roof properly laid, the greater the amount of felt and pitch used, the greater the life of the roof. Ten-ply roofs have been laid.

The pitch, much stiffer than tar, is made by distilling off the lighter oils and part of the creosote oils from the tar. The melting point of the pitch, a very important matter, depends upon the point to which the distillation is carried and the amount of free carbon. This should be varied somewhat to suit climatic conditions. Pitch for use in the autumn in Winnipeg would be very difficult to work in New Orleans in the summer. The melting point of the pitch is not definite and in defining it a special specification is necessary. The use of a pitch with a melting point too high to allow satisfactory working and requiring additional fluxes on the work, giving a "cut-back" pitch, is very liable to give uncertain results and should not be allowed. Worse than this is the use of tar or soft pitch stiffened by the use of land plaster, portland cement or similar materials. This is not only uncertain in its results, but it gives a product having a short life. The best practice allows the use of nothing but straight run, coal tar pitch.

The coating of gravel, crushed stone or slag helps to hold the pitch in place, protects it from wear and from the action of

the elements and has considerable fire retardant value. If the material be too fine its holding power is lessened. If it be too large the stones are more apt to roll off and to damage the roof when it is walked upon and the pitch is not properly protected. Crushed material with its rough, sharp edges has a much better holding power than rounded gravel. It can be used to help get results on a steep roof. Sand or dirt with the gravel is objectionable, as it tends to prevent the gravel from bedding in the pitch and sometimes it mixes with the pitch, the resultant being more inert and liable to crack than the clean pitch.

In the final coating of a coal tar roof the effect is to get the maximum amount of pitch coating which can be kept in place. The flatter the roof the greater the amount of pitch that can be used and the better both pitch and gravel will stay when put in place. The best results are obtained when the slope of the roof is only enough to allow it to thoroughly drain. When it gets above two inches to the foot many object to its use, but the above specifications are considered by others as good practice up to three inches to the foot. Above that incline a built-up coal-tar roof, using these specifications, is of double economy on permanent buildings, though fairly good results have been obtained from roofs steeper than this without special precautions. One method which gives good results is the addition of some asphalt to the pitch which is used for the top coating. This must be carefully done, as an intimate mixture of the asphalt and coal tar pitch is not easily obtained. The coal tar is often prepared for use on steep slopes by the addition of some finely ground inert material which, as previously stated, is liable to give uncertain results. Actinolite is preferred for this purpose by some of the best roofers. Portland cement and land plaster are used, but do not do as well, having chemical action on the other materials. Pitches prepared in this manner are perhaps to be preferred to stiff straight run, coal tar pitch or asphalt where skilled workmen are not available, as with the latter more skill is required in application. Slag is better than rounded gravel for steep roofs.

When a built-up roof is in need of repair it can frequently be kept tight for a considerable time by patching and recoating

as may be necessary, with pitch and gravel. When the original roof was well laid it can be repaired by scraping off the coating of gravel and laying a new two or three ply roof on top.

Tile or brick can be substituted for the gravel or slag where the roof is liable to have much wear and when the structure warrants the expense. The tiles are sometimes grouted in portland cement, but a bituminous cement is usually considered better. Properly built this makes almost an ideal roof.

The built-up coal-tar roofs have shown by many years trial their value for protecting flat roofs. Instances where a life of from twenty to thirty years has been obtained are not at all rare, but poor results due to poor workmanship and poor materials are not new. Pure coal-tar and coal-tar pitch are still made, and the dealers in roofing materials can, if they desire, furnish materials as good as any which have been sold in the past. Such materials, of course, are not the cheapest and where competition is severe the quality is liable to suffer. About all that can now be done to get the desired results is to be willing to pay the price and trust to the dealers.

The chances for poor workmanship are many and the most thorough inspection is very desirable. The moppings between the felts can be slighted, the flashings and work around gutters and openings neglected, the materials may be adulterated on the work and the quantities of pitch and gravel cut down. The cost of materials and the cost of laying for any job can be estimated within close limits and no contracts should be let which will require a slighting of the work to avoid a loss.

DISCUSSION

ASBESTOS ROOFS

By George R. Folds*

Asbestos felts are 95 percent pure asbestos fiber which is obtained by disintegrating the asbestos rock. Asbestos being a stone, it is non-tubular, non-porous, will not burn, is not affected by such acids as would come in contact with a roof, and will not decay under any condition.

District Manager, H. W. Johns-Manville Co., Pittsburgh.

So-called "wool felt" is made from refuse garments, rags of most every description, old carpets, straw, old newspapers and tailor shop and carpet factory sweepings. They contain about an average of 20 percent wool. They are, however, either animal or vegetable fiber of some sort. There is a great difference in the saturating qualities and strength of this material, depending on the selection of the stock and process of manufacture. They will rot, burn, are porous, tubular and are affected by acids. A comparison of properties indicates that asbestos felt is free from the natural defects inherent in untreated wool felt.

One asbestos impregnating, saturating material is natural asphalt, softened by carefully selected petroleum residual oil. It loses when subjected to heat at 325 deg. for seven hours about three percent of its weight. Coal tar, which is used for saturation, may be tar from water gas, a coke oven or a gas plant which uses bituminous coal.

As has been explained, these tars contain nearly all of their very volatile oils, and when subjected to the same test as asphalt, lose 15 to 20 percent against three percent. The residue of asphalt after heating, as described, is soft, pliable and full of life. The residue of tar after heating is a very hard pitch, containing soot from 12 to 35 percent, depending on the origin of the tar.

As to which of these two materials will stay plastic, thus being alive, the longest when subjected to atmospheric conditions, it has been the writer's experience that asphalt is the more dependable.

When impregnating asbestos fiber sheets they are slowly drawn through asphalt at a reasonably high temperature, slowly enough so the fabric will soak up sufficient asphalt to coat every fibre, cementing them securely together, thus producing a plastic, bitumenized waterproof sheet of stone.

Referring to the question of the relative value of tar pitch and asphalt:

Pitch is a product of bituminous coal or water gas, and is the result of distilling tar by which process a sufficient amount of the lighter oils are taken off until the residue is of

the desirable consistency, at this consistency the remaining oils are still very fugitive, the roofing pitch losing, if subjected to the customary test of subjecting the material to 325 degrees for seven hours, over 12 percent of its weight, the residue being a very hard pitch and would not, in this condition, be at all suitable for roofing purposes.

Trinidad lake asphalt roofing cement is a combination of Trinidad lake and other asphalts fluxed or softened with proper asphalt base residual oil. It is a natural product and is therefore supposed not to have been in any way damaged by over heating. Its melting and softening point is considerably higher than coal tar pitch; it will not run or "shove" in the summer or become as hard and brittle in winter as coal tar pitch.

It is very much less susceptible to atmospheric changes than tar pitches, and it does not rot under water. It loses, when subjected to the regular test to determine its volatile nature, about two percent against about 12 percent for pitch. The remaining asphalt after so heating is soft and pliable and full of life, while pitch is hard and flint-like.

The results of these laboratory tests for durability would serve to show that asphalt properly refined and combined is less volatile, has longer life in a plastic condition, and will act as a waterproofing cement for a very much longer period of years than tar.

Tar and asphalt will not properly mix, and if used together there is liable to be failure. The practical side may be best illustrated by considering the duty of bitumen in a street pavement. The bitumen is the cement which holds together the mineral aggregate composing the pavement. The top or surface of an asphalt pavement is composed of 90 percent mineral in the form of sand, ranging in size from dust to coarse, sharp particles. This is cemented together and naturally the pavement ceases to be when the bitumen ceases to cement. When it is properly mixed, asphalt performs this duty for a great number of years under most severe conditions—conditions which no roof would be called upon to contend with.

Coal tar pitch will not perform this duty because it cracks in winter, runs and "shoves" in summer, and the pavement

soon disintegrates because it ceases to act as a cement, and therefore is not used.

Asphalt has been used for the past thirty years most successfully for roofing purposes. It has failed, but when it has it was not so much due to the asphalt as to those who used it or made it into a cement.

We have then a composite, all-mineral roof, made of materials that will not rot, a felt that will not assist in carrying off the volatile oils in the cement because of its non-tubular nature. As a matter of fact, asbestos fibre felt retards capillary attraction and seals the bitumen lying under it. It will not burn because the fabric is a stone, and the asphalt sealed under it might glow until it cokes, but does not flame or carry fire and is thus practically fireproof.

We do not need slag or gravel because the asbestos fiber felt performs the same function that slag or gravel does, eliminating the weight and permitting a clean, smooth surface, on which dirt and decay will not collect, making it easy to quickly locate leaks when necessary, and containing nothing that will fill down-spouts and gutters until they clog.

Built-up composite roofs over boards are constructed about as follows: First a composite sheet composed of one untreated pure asbestos sheet and one treated sheet, made at the factory, is laid on the roof boards, lapping and cementing, and nailing the sheets every two inches, with the white side down; following this with two more sheets of impregnated asbestos felt, placing these succeeding sheets so as to always break joints and having the next nailing in the center of the sheet thereunder. All nails are on the under edge, thus being incased in asbetsos and asphalt, and each sheet is fully mopped its full width, not half way, or just a few inches back; thus a composite sheet with every inch thoroughly cemented from bottom to top, and with every joint broken is secured.

A roof over concrete is the same as over boards, except three impregnated sheets should be used as described, first coating the concrete with a special liquid coating, making it possible to positively stick the hot asphalt to the concrete surface.

REINFORCED CEMENT TILE ROOFING

By J. de S. Freund*

Of all the vexatious problems that confront the mill owner, there is none so important as the roof which must protect his manufacturing operations and operatives. Owing to its great importance it demands considerable attention at the inception of the plant when the different types are considered in so far as are concerned their durability and efficiency, and last but most important, the yearly maintenance cost. The builder of today realizes more and more the necessity for permanent construction and protection against fire losses. Still, the mistake is made in using wooden sheathing as the base, depending on the fireproof qualities of the outer covering which is efficient as such, but affords no protection on the inside.

In considering and specifying the type of roof to be used, the works manager wants a roof reasonable in cost, one that is weathertight and waterproof, one that will withstand the noxious gases found in certain industries, and it must be fireproof and free from the usual expensive yearly maintenance charges.

The desigining engineer will demand concrete as the protecting medium, and with this as a basis, the construction must be moderate in weight, dense and compact in order to allow sufficient protection for the reinforcing metal which in any event must be near the under surface to overcome the weak feature of concrete. The roof must further be impervious to moisture from the outside and allow for expansion and contraction, thus preventing cracks.

The Germans, as the leaders in concrete construction, were the first to make a cement roofing tile. In 1868 an inventor in East Prussia devised an interlocking tile, but it remained for Leckert of Coburg, Germany, a clay products manufacturer, to perfect it. He tamped and formed his tile on plates, but was confronted with the difficulty in making it waterproof. He finally hit on the idea of boiling them in tar for about one minute which proved effective but damaging inasmuch as the tile disintegrated in a few years.

*Secretary, American Cement Tile Mfg. Co.

Thoman, in 1872, first made a diamond shaped interlocking tile, but he also resorted to the tar boiling process, later experimenting with the coloring and waterproofing of the surface. A coating of neat cement was tried but abolished on account of the crazing features. Cement colors were invented in the early eighties by Zernau of Halle, Germany, and first manufactured in Darmstadt but unsuccessfully. Shortly after, they were perfected, and you will find in Germany today, many of these first Cement Ziegel Dacher in actual service, in fact more stone like than ever, having withstood the ravages of weather and climatic conditions.

In 1895 Mr. Joseph Freund who lived in Coburg, Germany, at the time and had been in constant touch with Leckert, came to the United States and a company purchased the rights to manufacture in this country a number of the small standard types of cement tile. A plant was first in operation in Detroit, Michigan, and this was the beginning of the cement tile industry in this country, the first roof of its kind having been erected on the Stanton residence of that city in 1897. This roof was of the Spanish type and was considerably cut up with hips, valleys, towers, etc., and since that time has not cost one penny for repairs, and the color is a bright as ever. After that a large number of roofs were erected throughout Michigan and Ohio, all giving the same thorough satisfaction after ten to fifteen years service.

In 1899 the plant was moved to Pittsburgh, and it was at the suggestion of Mr. Garlinghouse of the Jones & Laughlin Steel Co. that a tile 24 in. by 24 in. was made, and which later developed into a reinforced interlocking tile three and four feet long. In 1902 the first large roofing tile for mill buildings was made, sizes 26 in. by 50 in. and laying 24 in. by 48 in. to the weather. This tile was ⅝ in. thick through the flat with a complicated head and side lock, reinforced with one by two expanded metal of 27 gauge. Lightness was aimed at, the tile weighing but 8½ lb. per sq. ft., but it was found that there was not sufficient body as the metal sheared the material. After considerable experimental work the present tile was developed as the most practicable, so that we now use an 18 gauge metal

with a thickness of 7/8 in. through the flat of the tile, while a heavy rib in the center and a side roll to form the interlocking feature, both add stiffness and rigidity.

The tile are of the best portland cement and sharp washed river or lake sand, made on steel pallets in a machine, and tamped by hand so that they are dense and compact. Before being placed on the cars to set, they are covered on the surface with a red waterproof coating. This coating is worked into a previously semi-finished surface so that all pores are thoroughly filled in and in addition is from $\frac{1}{32}$ to $\frac{1}{16}$ inch in thickness. The tile are removed from the pallets as soon as they can be handled and stacked in the warehouse to be shipped in from thirty days upwards.

In number of tests made, the tile have been found to carry from 1800 to 2000 lb. uniformly distributed load under a four foot support, or from 225 to 250 lb. per sq. ft., which in itself is more than they are ever called upon to carry in actual service. It is found that at total collapse the deflection in the center is from 5/8 to 3/4 in., and until the elastic limit is reached, the tile assumes normal state if load is removed.

In attempting to adhere too closely to a theoretical feature the reinforcing metal was formerly placed so close to the bottom that the metal was actually exposed in spots so that wherever subjected to noxious fumes, it corroded so that it was found necessary to place it approximately 1/4 in. from the bottom surface. This covering we find to be ample with the very dense and compact mass and is all that is required.

In the design of steel work required to carry cement tile, all that is required is the proper spacing of the channel purlins, laid approximately four feet apart, braced with sag rods and diagonals to the truss where the load rightly belongs. The tile weigh 13 1/2 lb. per sq. ft., so that a total roof load of fifty pounds is ample in designing to care for all roof, snow and wind loads. In order to avoid the complicated box sky light which cuts up a roof so that one must depend upon metal flashing, a glass insert tile has been designed of the same size and shape as the standard tile, the insert being 14 in. by 24 in., with 1/4

in. wire glass. This tile can be placed at any point in the roof, thus affording ample diffusion of light.

While the average owner of today is unmindful of the general appearance of his plant, still considerable attention is being paid particularly in smaller plants to the aesthetic. The cement tile with its red coating appeals to the eye, and if this is obtained without additional cost, why not lean to the beautiful as well as to the economic features. With a total of some twelve million square feet of cement tile in service today, it has passed the experimental stage and is here to stay.

Mr. Samuel E. Duff: In the first place I think the Structural Section and the Chairman ought to be complimented for the session tonight, because it has touched a subject not ordinarily brought before engineers in quite so emphatic a way as has been done here tonight. The contrast shown here in materials and theory in the different types of roofing is brought to our attention very clearly. The only thing I see lacking, and it was probably impossible to cover it on account of time, is if a very clear sketch of the different conditions under which these roofs should be applied for I think it would show that the apparent differences are not so great in reality. One of the most important things in designing a roof is to get at, in the first place, the actual conditions that have to be met before the type of roof is fixed. I thing a great many first class roofs have been ruined because they have been put in places for which they were not suited, and on the other hand some perhaps inferior roofs have done a great deal better than would have been expected because the place for them and the preparation were ideal.

A detailed discussion of roofing materials is something I am not competent to carry on, but I want to say again that it is not often that there is presented to any society the genesis and the development of any subject the way it has been shown here tonight. We have had a description of the pitch roof, the original roofing of civilized man, and we have also had presented

the reinforced cement tile, which is about the latest effort in that direction.

It is perhaps a little unfortunate that we have not had more photographs of all these types of roofing and some detailed drawings on a large scale of the exact shape and appearance of them, showing the limiting conditions which were described by the papers, so as to enable engineers to decide these things quickly without the necessity of spending time in study. For a great many engineers who have important projects on hand and are responsible for results have not had just the experience which teaches them how to select these different roofings and how to know whther or not they are getting what they have selected. I think we could learn a great deal more if we went a little farther.

Mr. W. M. Judd: The question of roofing is one that comes up to engineers and contractors very frequently and sometimes, from troubles experienced, we are inclined to say that there are no good roofings and it is only a question of what is the worst. But as Mr. Duff has said, the question of selecting roofs is one largely of selecting a roof best adapted for the particular conditions under consideration.

The application of a roof is so largely a question of workmanship that the best of roofs may be so put on as to develop defects in time, and minor details which do not receive due attention may spoil the best roof that is put on. As in other engineering construction, a good roof is largely a question of careful inspection and good workmanship.

Mr. J. O. Handy: I beg to say that I share the feeling which I believe to be general among chemists, that asphalt is a safer material than coal tar pitch because it is less subject to change when exposed to the weather. I refer to natural asphalt, not to oil asphalts. I believe that coal tar pitch from water gas plants and from coke ovens may be quite inferior to straight run coal tar pitch, which is made by distilling bituminous coal. I feel sure that the skill of the workmen is a very large factor in bringing out the best qualities of either asphalt or coal tar products.

Mr. Duff: I would like to add a little in explanation of what I said on this matter of selection. I have reference to a concrete roof of raw concrete or concrete finished with a rich cement. We find that it is covered with very expensive roofing in some cases, while in others it is merely waterproofed with various substances. I would like somebody to tell us what pitch of roof we must have to waterproof that concrete by some form of paint or something similar or at what pitch can we leave the waterproofing off? Also how large an area of that raw concrete can we safely let remain without expansion joints? Those are just a few details that I personally would like to see reduced to a formula. The same questions arise in regard to a built-up roof. To properly protect the felt with a layer of pitch or asphalt where must we stop in the slope of the roof? And when we get to the critical point what is the best substance to use? I think a great many mistakes have been made right at this critical point.

Another thing that is essentially a part of the roof has not been touched on, and that is the gutters. Sometimes we think of a gutter as simply something that is hanging below the roof to keep the water from blowing into the windows. But in our great manufacturing institutions the gutters are sometimes far more important that the roof itself because the area covered is so great that it is impossible to shed the water entirely beyond the wall of the building and we must build some form of gutter which will be as tight as the roof, although subject to more severe conditions. And the characteristics of the gutter must sometimes conform to the characteristics of the roof. There are a great many details about the gutters that require careful study. Perhaps some of these roofing gentlemen here know something about gutters and we would like to hear from them. What do they recommend when they have a valley gutter in the roof where they cannot make the gutter by a continuation of their own roofing—which of course they will recommend if you give them a chance.

Mr. W. S. Babcock: I find that on the subject of gutters and flashing, engineers have a great variety of data. Next year

if I have the privilege of coming here, I will be pleased to give you something on that subject. The use of bituminous substances in flashings and gutters is very interesting to us. There is apparently very little written on it. Conditions are different in different climates and we would be very glad to go into that.

Mr. G. R. Folds: We flash and counterflash with our asbestos roofing materials, and also with our asbestos roofing with galvanized iron or copper counterflashing and sometimes with metal standing flashing. Where we use any galvanized iron we always paint it, preferably on both sides, with a roofing paint. Where we use our own material we use one of our prepared roofings, which is made with burlap center, and one or two plies of impregnated asbestos felt on each side and cemented together with asphalt compound.

We make gutters with the same material as we apply on the roof proper. On built-up roofs we always recommend one or two additional plies in the gutter. These extra plies are generally laid first and often permit the material on the roof proper to run from the roof across the gutter, giving a very neat appearance.

We have recently laid asbestos felts in a gutter of one of these cement tile roofs where the gutter was against another building, the wall of which stood 12 ft. above the gutter. It was decided that the tile gutter was not large enough and we filled up part of the tile gutter with cinder cement and over this we put about one inch of our asbestos insulating cement, a regular boiler cement which has no waterproofing qualities at all, but which was used to keep as much heat as possible from underneath the roofing material. There were furnaces in the building and in the one next to it, from the windows of which heat averaged about 135 degrees. We laid the roofing material cross wise in the gutter, carrying it upon the wall of the adjoining building to sufficient height, and fastening it to the slabs of that building with wooden strips bolted on and set in asphalt. On the roof proper we ran the felt up over the second slab tile, cementing the felts to the cement covered gutter and to the tile. Where we turned the felts over the top of the second

row of tile, the third row of tile was let down on top of them. This gutter has not been on sufficiently long to serve as a test.

In regard to the pitch of a roof, we claim that no matter how steep the roof is it ought to have waterproofing. We have laid our material on roofs with very severe pitch. We have laid a great deal of roofing on book tile, about one-fifth pitch and we have laid a considerable quantity on roofs with one-third pitch. Our experience is that we have to be very careful on pitched roofs. On such roofs it is much safer to provide for an occasional nailing strip, although salesmen may say that it it not needed. Such hot weather as we have had this past summer will make a roof creep and we should provide against it.

Mr. S. E. Duff: I do not see anybody here to talk about the Ludovici tile. I think this is very unfortunate because there are some good clay tile. I put a power house roof on about eleven years ago of Ludovici tile on steel purlins 30 deg. pitch. That roof is over electric machinery and it is there yet. Nothing ever happened to it except that the wind came along one day and pulled a lot of tile off the purlins. They were not wired or fastened at all. Lately I cannot get any one to tell me that the little Ludovici tile is any good. I would like to know why.

Another thing I would like to know is why we do not have any slate roofs to speak up here. I know that a fairly good slate roof can be laid directly on steel for I have done it myself.

Speaking of gutters, these gentlemen recommend that their roofing be continued right down into the gutter. That is an easy solution and generally a very good one. Mr. Freund neglected to tell us in his talk of the very interesting examples of cement tile gutter which he has built. Perhaps some of you would not believe that you could make an absolutely water proof, an absolutely tight gutter with cement tiles, but you can and he can tell us how to do it.

Mr. J. de S. Freund: The gutter we invented is rather novel in its features. It is six feet in length and there is no special steel work required except the purlins to carry the joint pieces. The pitch in the gutter itself is varied in the various sections, in other words, we have seven or nine different lines of

gutter tile, the total drop in each six feet being about 3/4 in., so that each section varies in depth. The gutter tile is finished the same as the standard tile with the red top surfacing and reinforced with metal and rods and there is also a reinforcing concrete section on the lower side. The joint is made by means of a rabbett on the end of the gutter section which is laid on the joint pieces which are shaped like a letter *C*. Then after the joints are placed and the sections laid on them the bearers are filled with an asphaltum componnd and made tight in that way. After the gutter is laid in place the tile above this are bedded right on the flat surface. We have placed a great many thousands of feet of this gutter and it has proved very satisfactory.

Mr. G. R. Folds: We have an asbestos shingle which we believe has much more merit than slate as it is much more flexible and does not break like slate and can be cut with a saw. It is growing in use very fast not only among architects for residences but among engineers. They will undoubtedly give very much longer service where a roof is liable to have any sort of rough treatment. The asbestos shingle is made in a press of asbestos fiber and hydraulic cement. For a long time the only shingles offered for sale in this country were made by one firm on a paper making machine, each layer being rolled out.

Mr. W. M. Judd: Are the asbestos shingles ever applied except upon wood sheathing?

Mr. G. R. Folds: I have never known them to be applied on anything but wooden sheathing except on cement and used in place of tile. I presume it could be done and in fact we have offered asbestos wood, which is a very similar material to asbestos shingles. Of course such a sheet would not carry any great weight and could only be used where the roof would not be walked over, and where the purlins were close together.

Mr. S. E. Duff: I have neglected to go back to the beginning in roofing and to talk about the wooden shingle. It is a roof we do not want to forget, because out in Oregon and Washington they have shingles that last about as long as any roof we have heard about tonight. There is one thing I am surprised

Mr. Babcock has not brought out, for it seems to me it is one of the greatest arguments for his type of roof, and that is the fact that it is not always worth while to buy the best roof. There are a great many buildings in this country which are more or less temporary in character and in which the frame work and construction throughout are based on that theory. The builder is confronted with the question of putting on a roof which will not leak and which will have at least as much life as the building is expected to have and at the lowest possible cost. I am not an expert and I do not know but I suspect that Mr. Babcock could make a pretty good argument for his type based on the fact that a pitch roof is the cheapest good roof that you can put on a cheap building. I think that is a strong point in the discussion of the difference in value between roofs made with pitch and those made with asphalt, asbestos or any of the high priced materials.

Mr. W. S. Babcock: That question often comes before us. If they want something cheap, we advise probably two layers of felt. A roof that is well laid in three ply will last five years. If they want a more permanent roof, four plies of pitch and felt properly laid will last ten years. When you come to add an additional ply of felt and mopping of pitch, it will last anywhere from 15 to 20 years. With a coal tar pitch roof, it is advisable at the end of 12 or 15 years to remove the slag and recoat it, and put on one to three plies of felt with moppings of pitch. The idea is that there should be a negative and a positive, making a unit. The felt should be soft and sufficiently absorbent to absorb the pitch and combine them together in to a perfect unit. In coal tar pitch the heavy waterproofing oils in the pitch work down toward the bottom of the roof, and the lighter oil volatilizes and passes off, leaves a carbon deposit. The life of a five ply roof, as shown in the specifications which I have given here, is about 15 to 20 years. By adding another ply after 12 years service and two moppings of pitch, you have lengthened the life probably ten or twelve years.

In a built-up roof, we never advise a pitch beyond three inches to the foot. If a higher pitched roof is required you

should use a different material, or use coal tar pitch in a different form. Beyond six inches to the foot, we do not advise the use of coal tar pitch under any conditions. It all depends on the location of the roof. Each condition is different, and advice is given accordingly.

Mr. G. R. Folds: We put on concrete roofs one ply or two ply or three ply and sometimes more. With our material whenever it is desired to add anything to the roof it can be just mopped on, one or two of three ply. There is nothing to take off.

Mr. L. P. Blum: I do not desire to contradict the last speaker's actual experience; last winter however there came under my observation a round house built with monolithic reinforced concrete roof by one of the railroads in the Pittsburgh district. I was assured by the engineer in charge that there had been no attempt made to roof or water proof it, and he assured me that they had gone through one winter without having any trouble.

Mr. G. R. Folds: We have recently waterproofed a round house which was not water proofed at first but they had to do it.

Mr. W. M. Kinney: In order to produce watertight concrete where spread over large areas, it is necessary to avoid expansion and contraction cracks by the use of reinforcement. If, through poor workmanship or lack of such reinforcement, these cracks appear, it is an easy thing to apply some impervious coating. However, there are several instances where reinforced monolithic roofs have given entire satisfaction.

As to the use of waterproofing compounds, the Joint Committee on Concrete and Reinforced Concrete advise that they do not recommend any form of waterproofing compound. They believe that, with proper mixing and placing, concrete can be made impervious to water. To absolutely insure watertightness where the concrete is liable to be imperfectly made or subjected to considerable pressure, asphaltic or coal tar preparations applied either as a mastic or as a coating on felt or cloth fabric is recommended.

It would seem, however, that if the money spent in the treat-

ment of concrete for purposes of waterproofing was used in producing concrete proportioned and placed to render it impervious, more lasting results would be obtained.

Mr. J. de S. Freund: As the last speaker stated, concrete can be made practically impervious to moisture. But in order to do so it must be compact and dense. This is something that can not be done very well on a monolithic roof, that is built in place. In the many forms of reinforcement that are used the concrete is plastered both on the top and under side, and you can see that with the material constantly giving under the pressure of the workman, who uses nothing but a trowel, it is impossible to get a thoroughly compact mass and it is for this reason that you have to resort to an outside covering of some kind. Slabs built up on the ground are thoroughly tamped and are bound to be practically impervious to moisture so they will stand up much better than any monolithic roof, and only for the reason that it is made properly.

Mr. W. M. Kinney: One roof occurs to me that is absolutely monolithic in structure and there has been no waterproofing or any other method devised to protect it to prevent water from penetrating through it. It is a troweled surface and there was no attempt to treat it after it was put in.

Another interesting but of construction is a cinder concrete roof on which was nailed ordinary slate. I think that is one of the rare cases where slate was nailed directly on concrete. It worked very satisfactorily. Whether, if the concrete was a little bit older they would have been able to nail it I do not know. They managed to get it in satisfactorily.

ACIDS IN THE MONONGAHELA RIVER

By Thomas P. Roberts*

The object of this paper is to promote efforts to mitigate the evils resulting from the unrestricted use of water courses for carrying away harmful fluid discharges from mines and mills and give some observations on the phenomena attendant upon acids in the Monongahela River.

The evils referred to have reached, in the Monongahela, such vast proportions in recent years as to bid fair to render it unfit for the navigation of the ordinary type of steamers and very costly for power plants using the river water for making steam.

We live in an age, however, when the question of what constitutes a nuisance is not so easily settled as it was in more primitive times. Smoke, and ore dust, fumes from oil refineries, and the bucolic odors from cattle yards, are all recognized nuisances which every one agrees should be abated, *provided,* their abatement works no serious injury to the welfare of the interested community. There are some laws, also, to be put into execution, the highest court of the land has determined, only as "reasonably interpreted."

It may, therefore, be held, in the case of acids reaching our rivers, that such method of disposal need not be totally prohibited, but may be permitted under "reasonable regulations." In this view of the case, therefore, it would be well to determine as speedily as possible what constitutes an allowable maximum, or percent of acid in the river with relation to its varying discharge. In other words, determine the times or the rate at which acid wastes may be permitted to flow into the rivers from manufacturing establishments, and from

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coal mines. The problem is not so simple as it may appear on first thought, but the writer is prepared to affirm that there is one regulation, as to mills, easy of application, and promising to work no hardships to them, and which would materially decrease damage from acid, viz, to forbid the too rapid emptying of pickle vats. Their emptying in a rush results in the formation of areas of intense acidity, which move along the shore. A steamer landed, with its pumps in operation, in a high acid area may get in a short time as much acid in its boilers as would require several hours for the pumps to take up in the open river where coal mine acid, from the headwaters, is more evenly commingled with the discharge of the river.

Owners of our steel mills have never, to the writer's knowledge, made any concerted effort to abate the acid nuisance in the river water, but have one after another chosen instead to invest large sums of money in the erection of softening plants where the water, before it is permitted to reach their boilers, is treated usually with soda ash and lime to neutralize it. We have examples of companies, owning a number of mills, letting acid into the river from one plant which is bound to increase the difficulties at another of their own plants farther down the Monongahela. The cost of operating softening plants is very considerable, being several hundred dollars daily, the writer understands in some cases.

Besides the enormous consumption of soda ash in treatment of boiler water, there are establishments where it becomes occasionally necessary, in order to save pipe lines laid in underground drains from rapid corrosion, to place great quantities of the soda ash in the drains.

It would be desirable to know, at least approximately, the number of, and the amount of money invested in water softening plants in the Pittsburgh District; also, to know the cost of maintenance and repairs. Perhaps with such facts before them the captains of our great industries would be disposed to put their heads together and find out if something could not be done to reduce the cost of steam production. The aspect of affairs along the river is not so attractive as it should be to

strangers seeking locations for new plants. Water should be had for them reasonably pure if by any means possible, but the chemical symbol for water just now in the Pittsburgh District has many more letters than formerly, some of which are suggestive of trouble.

Time forbids more than a passing reference to the damages and expenses incurred by the domestic users of acid water in the Monongahela Valley. Its importance may be imagined from a few words; brass pipes necessary, mistakes in use of household softeners, ruining clothing in washing, potable water sold in bottles, etc., etc.

It may be that it is not practicable to so treat the water of the entire river as to make it soft as it was in its pristine state. There may be a question, also, as to the effect on the rivers of the reagents to be used in attempting to reduce its acidity, but it is scarcely to be supposed that under any system of treatment the "medicines" would produce worse effects than the disease they are intended to cure. Old fashioned lime scale on boilers, if it ever came to that, would be much more endurable on steamboats than leaky tubes, and holes in boiler plates, now so frequently in evidence.

According to the investigations of Mr. Charles E. Ashcraft, Junior Assistant United States Engineer, Pittsburgh office, much the largest proportion of the sulphuric acid reaching the river comes from coal mines. He has ascertained that of the twelve galvanizing establishments on the Monongahela River, or its tributaries, eight of them are estimated to use 59 200 tons of acid per annum. The four plants not included in his estimate are very extensive users, and it is probably within the mark to say that 75 000 tons of acid are annually consumed in the district. One of the establishments finds a profit in converting its spent acid into copperas, while several others waste but little acid. At one establishment the waste acid reaching the river amounted to about six percent of the annual consumption. Data are lacking as to percent of waste for a number of the more important plants. On the assumption that the waste acid from the twelve plants reaching the river forms two

percent of their total consumption, the amount would be about four tons daily reaching the river.

In 1882 the writer first observed the process of coagulation and the rapid clarification of muddy water in the Youghiogheny River, effected by very black looking water from coal washers on Jacobs Creek mingling with that of the main stream, the result being water of sparkling clearness. The first appearance of acid-clarified water at Lock No. 1, Pittsburgh, due to mine water from the Youghiogheny, was in 1891. It is to be remembered that the Monongahela River prior to the last date mentioned was never known to become quite clear. The clay from its banks yields material so exceedingly fine as to require long periods of quietness before it will settle. In more recent periods, however, the bed of the river has been seen with perfect distinctness to a depth of 14 feet. Samples of the water upon the particular occasion referred to, after standing for several months, showed no trace whatever of sediment nor under any light was there any tint or color. Usually, however, boats keep the water churned up so that it is not often transparent beyond a depth of four or five feet. The precipitate on the river bed is generally of an orange red color, and boats of large power when running at full speed stir up the bottom and often leave a red trail behind them. This effect has been observed where the depth was 15 feet or over, the temporary red trails being in striking contrast to the "ocean blue", or sometimes greenish blue, of the river in general during the summer months.

With the development of mining operations, especially in West Virginia, and the erection of manufacturing plants in recent years, there are times when the entire river is artificially clarified as far as Fairmont, 130 miles above Pittsburgh. As nearly as the writer can estimate there appears to be constantly in the river at Pittsburgh enough acid to make a showing of clarification with a discharge represented by three feet depth on a dam 900 feet in length. This would make a volume of water of approximately 15 000 cubic feet, or 112 500 gallons, per second.

It has been a desideratum to know the total quantity of

uncombined acid moving in the waters of the Monongahela and passing Pittsburgh. It is probably a quantity subject to but little daily variation after the point is reached that it has little work to do in making coagulents, i. e., clarifying the water. In respect to average daily movement, its range in quantity, or volume, is, therefore, very different from that of the water which transports it.

It appears that while the records of tests for acids available for study are exceedingly numerous, covering, as they do, daily reports from mills and pumping plants for a number of years past, nevertheless the records have not been co-ordinated with the river's discharge. This co-ordination would require tests to obtain the mean acidity of the entire river conjointly with measurements of the river's discharge per unit of time.

The best time for making such comparative tests and measurements would be after the passage of a freshet from headwaters which has swept the river from the West Virginia mines to its mouth so that no areas high in accumulated acid would be left in any of the pools. A favorable opportunity for making this determination under conditions mentioned occurred on September 21, 1911, when the discharge over Dam No. 1 was about 15 000 cubic feet per second, a decrease from 40 000 feet per second a few days before. Samples were taken from five well distributed points across the river at a point about 100 yards above Dam No. 1. The discharge was represented by about 3.9 feet depth on the crest of the dam for 720 feet of its length. The remaining 200 feet length of the dam was "shut off" undergoing rebuilding. For the entire length of the dam the same discharge would have given about three feet depth on its crest. The samples were taken from one foot depth below the surface. The determinations for acid were made by the United States Bureau of Standards at the testing laboratory, Arsenal Park, and were as follows:

TABLE NO. 1

Location— No.	Distance from shore. Feet.	Aspect of river surface.	Velocity— Miles per hour.	Free acid– Grains per gal.	Remarks.
1	Forebay of locks	Clarified	0.00	.099	Right shore.
2	50	"	0.25	.099	Distance from right shore.
3	200	Mottled*	1.00	.086	Distance from right shore.
4	Mid-river	"	1.20	.099	
5	125	Slightly muddy	0.25	.082	Distance from left shore.
	Mean		0.65	.093	Weather fair and warm; temp. of river water 70 deg. F.

*By "mottled" is meant minute particles of curdled clay or mud suspended in clear water, but so numerous that unless examined closely might be considered dissolved mud, or "muddy water."

The violent reaction below the dam broke up the curdling process, the color of the river from shore to shore becoming yellowish and nearly opaque. Next day, September 22d, all of the water approaching the dam appeared to be very nearly clear, the river in the meantime having fallen about four inches. With a discharge of 112 500 gallons per second it would appear from the above determination that there is carried daily by the river about 64.5 tons of free acid. With the discharge of the river reduced to 300 cu. ft. per sec., as occurs during ordinary low-water periods, the acidity of the river with the same quantity of acid would be increased 50 times, or to 4.65 grains per gallon.

It is necessary to have some clay or "mud" with the acid to produce a good coagulent, such as sulphate of alumina, and where all the clay is used up fresh increments of acids entering the river bring about other reactions, causing areas of the river to assume a yellowish color, or some times a chocolate brown, which might be mistaken for ordinary mud in suspension.

A rather interesting phenomenon observed by the writer at Lock No. 6, 70 miles above Pittsburgh, last November was to see the river as black as ink, though it was really transparent

for six inches' depth. Such a decided blackness was never seen before at No. 6 and indicated that acid from above in unusual quantities was combining with the tannin from natural sources, always carried by Cheat River water, and making a diluted ink. A peculiarity of this very dark water was that when waves dashed it against a rough, stony edged shore it developed masses of suds, or foam, floating on the water higher than the sides of skiffs moving through it. Altogether the writer began to think that hydraulics, as taught in the books, was in sore need of a supplement on "Chemico-hydraulics."

It has been found at some of the locks that in filling them through deeply submerged valves, the water introduced into the lock chambers was higher in acid than surface water. To settle this point, in one of the locks which was closed for repairs and containing almost perfectly still water, tests were made with the result that water drawn from twelve feet depth contained considerably more acid than that from near the surface,—in the case tried two grains per gallon more. It would thus appear that there is a tendency in the acid to gravitate towards the bottom, but as to whether in time the surface water would become neutral is an open question.

Sometimes at Lock No. 1, with a freshet in the river amounting to eight feet depth flowing over the dam, incipient clarification of the water in the forebay of the locks is noticeable. At such a time the phenomena can be observed of filling a lock with very muddy water from an apparently clear source. It may be believed, therefore, that clarification always proceeds from the surface and extends downward. Doubtless oxygen from the air at the surface has much to do with initiating the process of coagulation and clarification of water. Sometimes also with several feet depth on the dams streaks of clarified water 10 to 15 feet wide can be seen alternating with curdled, or apparently muddy, water streaks of about the same width. In this connection reference can be made to a paper read before the Chemical section of our Society by Mr. J. A. Mohr, June, 1901*, wherein he mentions that of five samples taken from

*"Acid in Monongahela River Water," by J. A. Mohr; Proceedings, Engineers' Society of Western Pennsylvania, Vol. 17, p. 237.

equidistant points across the Youghiogheny River, three gave decided acid, one neutral, and one gave an alkaline reaction. Had there been some mud in suspension in the river the vertical lines to which Mr. Mohr refers would have been plainly visible to the eye.

Several times within the past year the writer has observed a stream of yellowish, and, as he is informed, sulphurous water entering the river from a manufacturing plant in Pool No. 3. Mention is made of this place because the yellow water from the sewer acted in a peculiar way. Thus instead of accumulating in a segregated area to slowly move down along the shore in the usual manner, it appeared to expand and passed directly 700 feet across the river, and by some process of diffusion spread itself *upstream* along the opposite shore for about 100 yards. The line of demarcation, from shore to shore, between the tawney yellow and the clear "ocean blue" water above was very sharply defined. Downstream the entire surface of the river for about two miles partook of the opaque yellow color and increased the mid river acid content day after day from 0.2 grains in the blue water to 2.0 and sometimes as high as 4.0 grains per gallon in the yellow water.

The only reason the writer can assign for the peculiar action of the yellow water was that it must have been hot, or at least very warm. It is his observation that hot water streams entering the river when it is low or with little or no visible current, propagate themselves in a very curious way, sometimes wandering entirely across the river, losing heat by radiation, as does the Gulf Stream, and not by mingling with the surrounding water. The writer made this discovery purely by accident several years ago. In passing up the river from the city in a motor boat, the temperature of the water was taken in mid river in Pool No. 1 at about 75 points in ten miles. The water ranged from 45 to 90 deg. fahr. with that of the atmosphere below the freezing point, the river being low with no perceptible current in the pools. Several stops were made in the warm belts to determine their limits, and places could be found where in a distance of ten feet, and even less distance, there were differences of fully 40 deg. in the temperature

of the mid river water. It was then observed that soot flakes rolling on the water's surface, as actuated by the breeze, would stop at warm water lines. The soot thus accumulating in strangely curved or sinuous lines rendered the hot water areas distinctly visible from the shore. The initial force of the entering streams of hot water had evidently nothing to do with the curves they took. The peculiar expansion of the hot water streams, always with a hot water wall in juxta-position to a colder wall, was possibly due to the different densities of the hot and cold water. That the matter of temperatures of mill sewage may have considerable weight and bearing on the regulation of acid discharged into the river seems to be a reasonable conclusion, if the writer's premises are tenable.

A very extensive steel plant on the river in Pool No. 3, during the fall of 1910, was on the verge of being closed down owing to the inadequacy of its devices for softening the river water. Never before had the company's chemist noted such acid conditions in the river. The plant would have been shut down had it not been that at the critical time the flashboards on Dam No. 4 were partially lowered in the hope of helping things for some pump and other boats in the Government service whose boiler tubes were giving much trouble. The stirring up of the river resulting from a sudden increment of water in Pool No. 3 raised the pools below only a few tenths; nevertheless it did a great deal of good, especially to the steel company referred to.

Already one of the railroads paralleling the river has extended a pipe line from a reservoir in the mountains along the river to meet the demands of its service. But as the conduit from the great Ashokan reservoir to New York City would scarcely have capacity sufficient to meet the requirements of our manufacturing and furnace plants, a water supply for them from the mountains is beyond a reasonable expectation.

Must steamboats be equipped with condensing engines, and thus be unduly weighted and with increased draught, or must they take in tow bulk boats holding Allegheny River water, as some of them do, to draw upon for steam making while on the Monongahela? The situation is only bearable now at a large

cost annually for repairs, while the future promises, with the rapid increase in the output of acid, the extinction of the well approved types of engines and boilers at present in use.

The great majority of the steamers place their sole dependence for safety in the use of boiler compounds, but as the proper doses of this stuff are largely a matter of guess work, there are chances for mistakes. As a rule, however, the engineers are on the safe side and overdose their boilers.

A friend suggests that storage reservoirs upon the headwaters can be constructed from which can be drawn a sufficient volume of water to dilute the acid to a safely usable point. Perhaps, however, if only a small part of the cost of such reservoirs were applied to neutralizing spent acids from certain mills, coal washeries and coal mines, found to be the greatest delinquents, the good work could be accomplished with much less capital investment. Some slight reservoir effect on the river would be at times desirable, but to permanently and materially increase the river current would be a detriment to navigation, and a source of considerable increase in cost of maintenance of the locks and dams, especially in the item of repairs. It might be better perhaps to extend acid pipe lines along the banks in certain stretches of the river, and at selected points neutralize the acid, thus having a few, instead of many, such plants.

The conservation of food supplies is becoming a matter of greater and greater importance to our people with the lapse of time but since the advent of acid in the Monongahela River the salmon and bass, which formerly abounded in its waters and in those of its larger tributaries, and furnished wholesome food to many persons, have become practically extinct. The fish died from asphyxiation caused by the absorption of the free oxygen in the water by the acid. They were not poisoned, as supposed by many, though it sometimes occurs that "self blood poisoning" is a concomitant of asphyxiation. Fish come up from the Ohio River in great numbers during the spring floods and are often caught while still alive at the surface, weak and struggling for existence, but in this condition they are apt to create sickness if eaten. To live healthily fish must get air through their

gills. Dilution of the acid by supplementing the river's discharge from reservoirs does not promise for the fish that certain desired relief that would surely result from stopping the acid from entering the water courses.

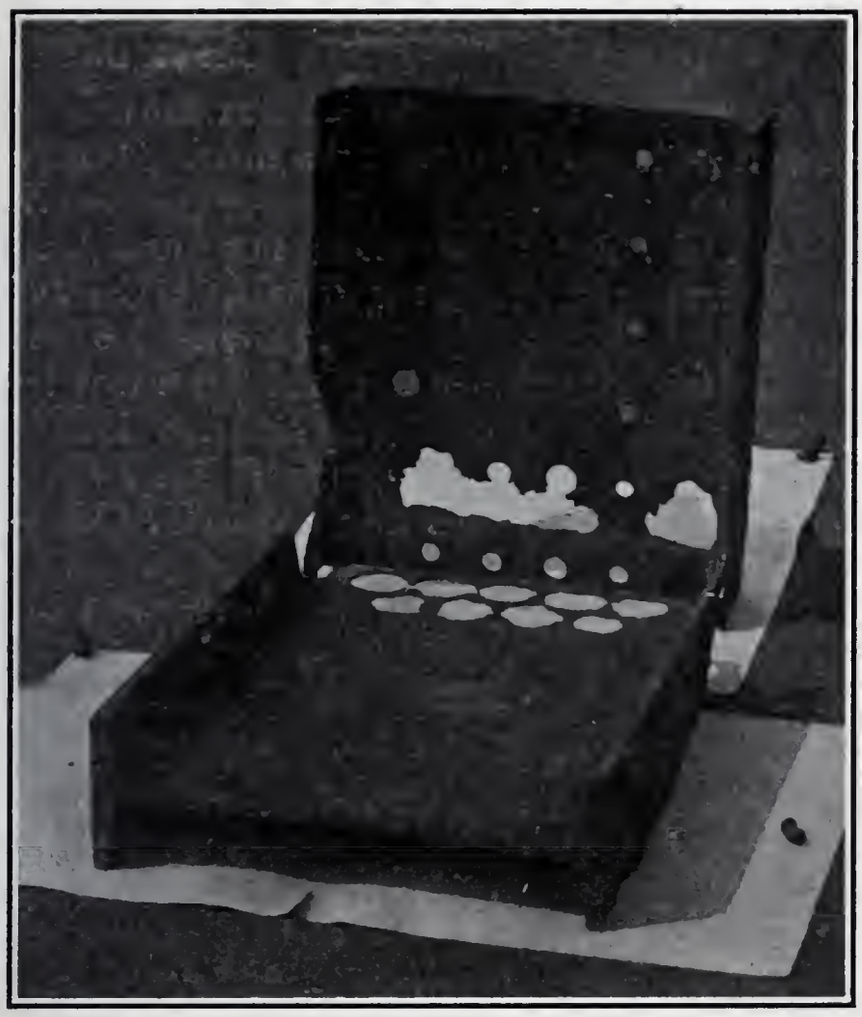

Fig. 1. Ends of I-beams from Lock Gates.

As before said concerning damages, financial and otherwise, to thousands of households, time forbids taking the items up in detail. This much, however, can be said that if we add such domestic items to the losses incurred by mill and vessel owners, there would be produced a sum which, if expressed in dollars, would be very much greater than that which would have to be expended in neutralizing the acid. Nor should it be forgotten that so great has become the demand throughout the country for sulphate of iron that a profit could be made in many instances by converting the acid into that merchantable material. It is just such overlooked matters that contribute largely to the high cost of and to the discomforts of living, so much complained of in Pittsburgh and throughout its surrounding regions.

Not only the mills and boating interests but the general Government as well is interested financially in the solution of the problem, for the lock gates, valves, wickets, miter irons and adjustable tops on the dams along the river are all subject to deterioration and call for frequent attention. While this trouble is present to a greater or less extent at all the locks, it appears in its most aggravated form at Lock No. 2.

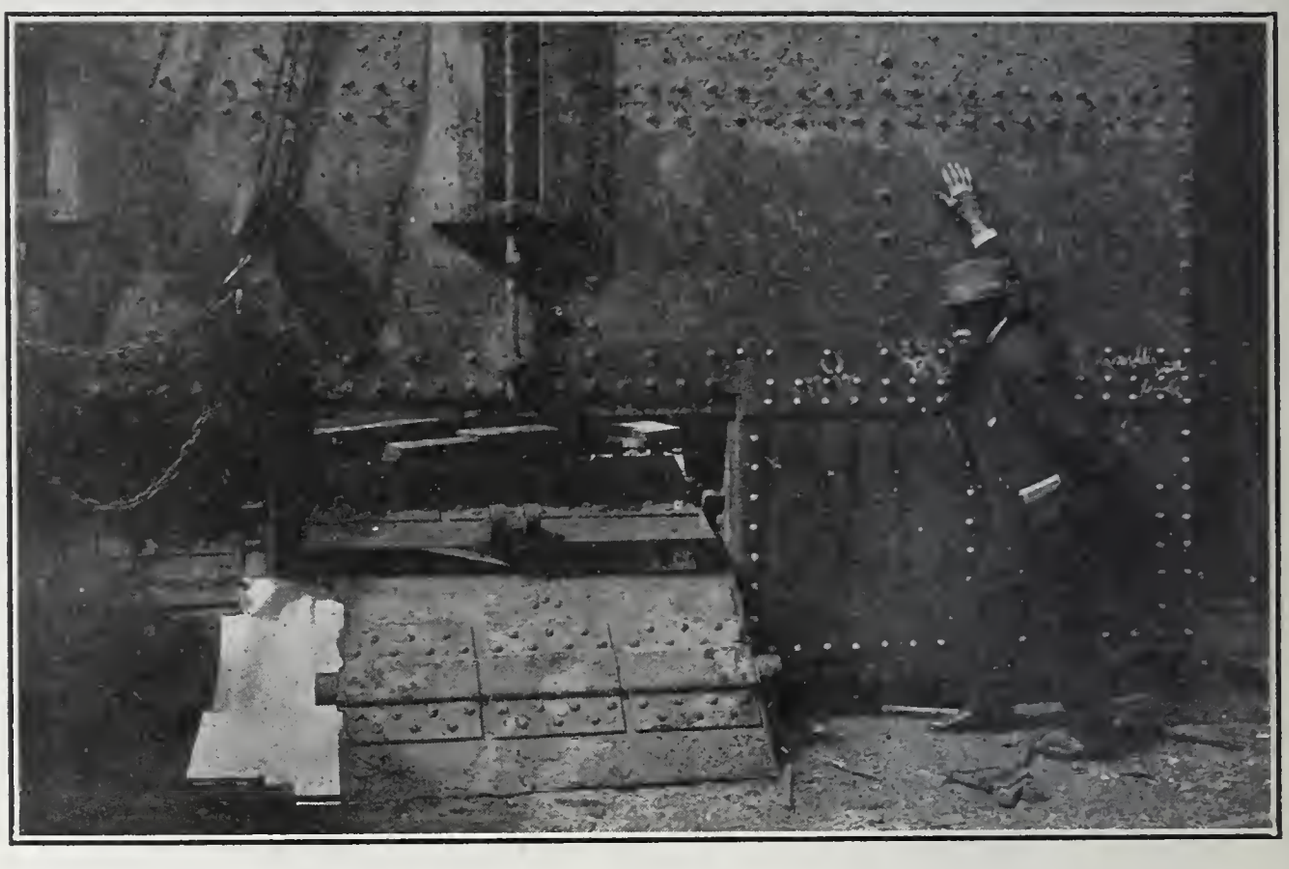

Fig. 2. Gate Wicket showing loss of several inches of metal, ¾ in. thick, at bottom of blade by corrosion.

Concerning the damage done by the acid at this lock, the photographs, here reproduced, speak for themselves. The short pieces of I-beams shown in the photograph were sawed from the end post and bottom beam at the lower corner of one of the lock gates. These gates had been in use about six years, see Fig. 1. The pressure determines the velocity of the water seeking outlets through crevices. The corrosive action appears to be as rapid about a small as about a large opening. Rivets not in the first place absolutely tight, are rapidly consumed, being cut away very often as though a gouge had been used to groove them. Edges of valves and gate wickets are also grooved in the

same manner, the metal being always clean where corrosion is very active, see Fig. 2. It will be observed that the wicket shown in Fig. 2 is very ragged at one end while the lower half of the blade is greatly reduced in width so as not to correspond with the top half—thus making a large permanent leak. The riveted work on the lock gate shown in the cut represent new sheets in place, the repairs having been completed. The holes in the plate steel, it is thought, are the outgrowth some times of rivets, which have fallen away from their holes, letting a current through. In other cases the holes may have been the result of deflected currents striking the plates with great force. The plate forming the 6 by 7 ft. valve shown in Fig. 3 was ¾ in. thick. The valve in question, while six years old, had only been three years exposed to strong currents.

Three years ago the miter sills of the lower gates of the inshore lock were shod with new angle steel ¾ in. thick with top leg on the sill, six inches wide, and vertical leg, eight inches wide, against which latter the lock gates rested when closed. After the lock was pumped out recently the vertical legs mentioned were found to have been entirely consumed by the acid. Evidently the current, in a very thin sheet indeed, had passed upward under full lock pressure between the gate and the sill, with its angle steel covering. As the gates were not in closed position probably for more than one-third of the time, and after further deduction of several months for high water with weak acid conditions in the river, we may assume that the corrosion of the ¾ in. metal took place in eight or nine months of effective acid duty. This with acid ranging from two to six grains per gallon in the water.

The action of acid is less rapid in the outer lock, though all four of its large valves have been removed for extensive repairs, and still less rapid farther out in the river, evidencing the fact that the acid was for the most part following the shore from Turtle Creek, which enters the river a few hundred yards above the lock. Turtle Creek water for the most of the time ranges from eight to twenty grains of acid to the gallon.

There is shown in Fig 4, a section of a pipe three inches in diameter which had been laid several years ago on the apron

of the dam to convey compressed air used in maneuvering the drums on the dam. The pipe was in such position that during low-water periods there was a fall of water dropping about two feet on it. What is remarkable about the pipe is that it was cut from a fifty feet length, all of which was about as full of ragged edged holes as the part shown, and yet the pipe was carrying air satisfactorily when needed until one day it was reported to have burst in *one spot*. Surely all the holes were not developed in one day, but it must ever remain a mystery how the pipe served its purpose without giving earlier and more numerous indications of its ragged condition.

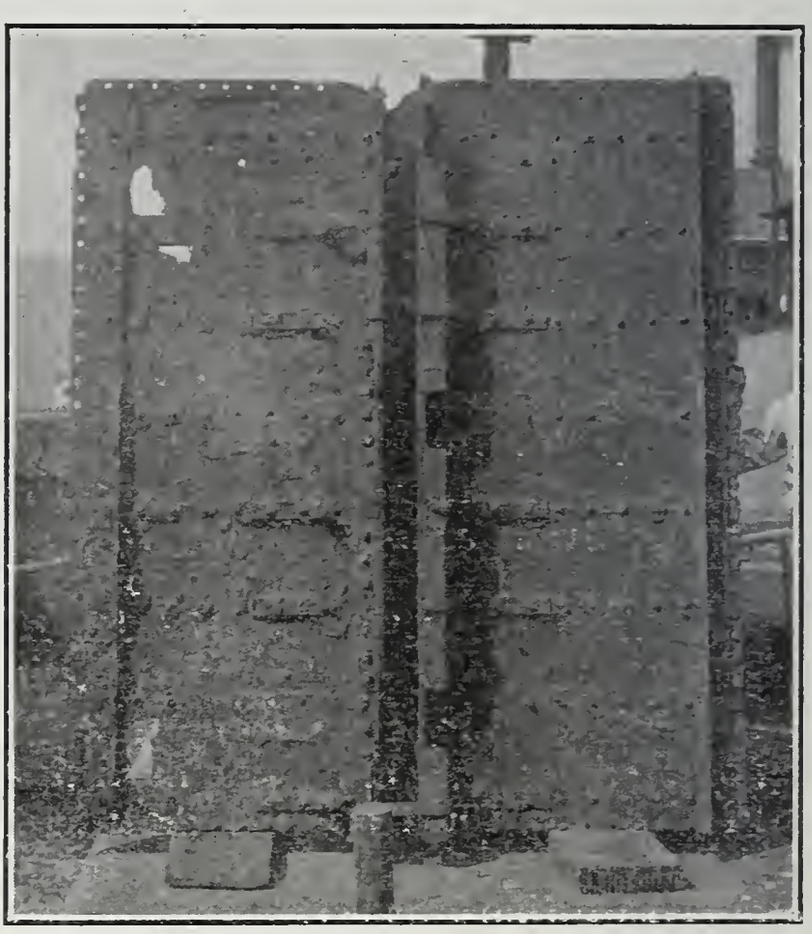

Fig. 3. Butterfly Valve corroded beyond repair.

The acid is very fond of attacking driftbolts ¾ in. square, at the spots where they have come through one timber and are entering the next timber below. A hack saw could scarcely be made to do neater work in cutting them off.

In Fig. 5 is shown the lower leaf of a steel bear trap gate of the type used in the dams of the Ohio River and it indicates the large areas of metal exposed to the action of acid waters in our rivers. After scraping off an eighth of an inch of orange red

deposit on the lock wall, the concrete surface, about six years old, was exposed to view. Here, as has been noticed at many other places, the action of the acid on concrete is next to nothing. Curiously enough in the conduits of filling valves the velocity of the water is often perhaps as much as 30 ft. per sec., or say, 20 mi. per hr., and yet the concrete side walls and roof are smoothly covered to a depth of ⅛ to ¼ inch with orange red deposit. It is strange indeed that the paint makers can devise nothing that will stick well below water and stand the abrasive

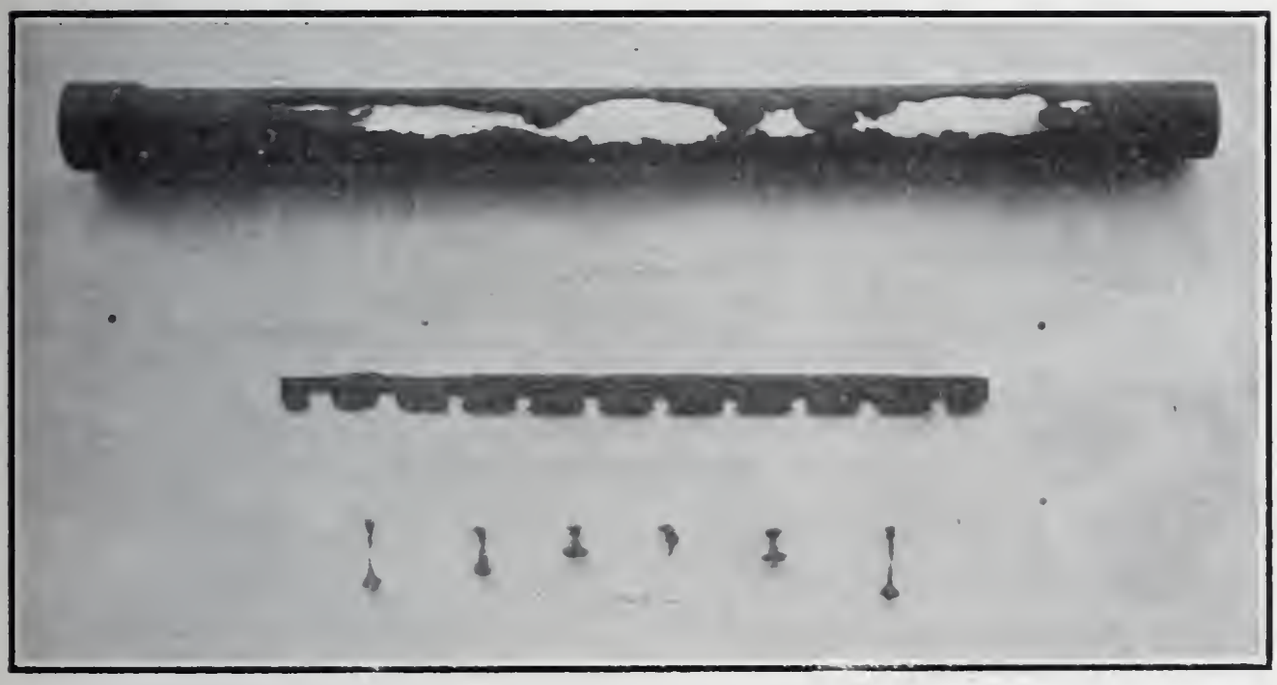

Fig. 4. Corroded pipe, rivets, etc.

energy of sand and mud when carried in suspension, yet here we have a tender felt-like growth of iron oxide which when dry falls off or crumbles with the slightest touch, but which when soft and wet withstands almost the force of a jet from Niagara, in the conduits of the Monongahela locks.

Cast iron parts below the later load up oxide with apparently little loss of metal. The experience with cast steel under water has been limited on the Monongahela River. In the case, however, of two plates two inches thick, which had been in a strong current for several years, their corners presented the appearance of having been chipped off as through by a hammer. Closer inspection, however, showed the peculiar conchoidal etching, or grooving, by acid noticed so often on corners of rolled steel plates.

As for wood, its durability must be indefinitely prolonged in water so free of oxygen and bacterial life. The acid, however, by preventing decay may cause more snags to become waterlogged and sink and thus endanger navigation. This idea is merely suggested as a matter of theory, not capable of being demonstrated by experiment. Submerged timber is certainly very durable in the Monongahela, but whether it be more perfectly preserved here than in other rivers, no positive opinion can be expressed.

Fig. 5. Lower Leaf of a "Bear Trap" Gate in course of construction.

For convenient reference there is here appended an extract from the Act of Congress approved March 3, 1899, relating to depositing material in streams or on their banks liable to reach rivers and interfere with navigation.

"Sec. 13. That it shall not be lawful to throw, discharge, or deposit, or cause, suffer, or procure to be thrown, discharged, or deposited either from or out of any ship, barge, or other floating craft of any kind, or from the shore, wharf, manufacturing establishment, or mill of any kind, any refuse matter of any kind or description whatever other than that flowing from streets and sewers and passing

therefrom in a liquid state, into any navigable water of the United States, or into any tributary of any navigable water from which the same shall float or be washed into such navigable water; and it shall not be lawful to deposit, or cause, suffer, or procure to be deposited material of any kind in any place on the bank of any navigable water, or on the bank of any tributary of any navigable water, where the same shall be liable to be washed into such navigable water, either by ordinary or high tides, or by storms or floods, or otherwise, whereby navigation shall or may be impeded or obstructed.****"

Since preparing the paper for the Society the author has received from Mr. J. K. Clement, Physicist of the U. S. Bureau of Mines, a statement regarding an interesting experiment which has been made recently at Lock No. 2 in the Monogahela River. The photographs of the steel plates "before and after" used by Mr. F. M. Stanton in this preliminary experiment tend to encourage the belief that the electrolytic method for the prevention of erosion devised by the Bureau of Mines will have a wide range of application. The continuation of the experiments on a larger scale has the hearty endorsement of Col. H. C. Newcomer in charge of river improvements throughout the basin of the Ohio River.

Mr. Clements statement follows:

"Experiments now being conducted by investigators of the U. S. Bureau of Mines, offer possibility of some assistance in the prevention of the corrosion of steel exposed to the action of acid waters.

"Although these investigations are being made with special reference to the corrosion of boiler tubes, and of steel used in mining operations their results may be of more general application.

"The method used in the experiments of the Bureau of Mines is based on the electrolytic theory of corrosion, which is now generally accepted by workers in this field. According to this theory when iron is oxidized in the wet way it first goes into solution as ferrous ions. The ferrous ions are then oxidized by the oxygen present in the water, to ferric ions, which are then precipitated as ferric hydroxide. At the same time that iron is passing into solution at one part of the surface an equivalent amount of hydrogen is liberated at another point. The passage of the iron from the atomic to the ionic state and of the hydrogen from the ionic to the atomic state is accompanied by a transfer of electricity, the electric current following in the direction from iron to solution at the point where the iron is dissolved and from solution to iron at the point of evolution of hydrogen.

"The tendency of metals to go into solution is known as "solution pressure" or "solution tension." The more positive a metal the greater is its solution tension: thus the solution tension of sodium or potassium is very high and that of gold is zero. The solution tension of zinc is greater than that of iron. If, therefore, strips of zinc and iron are immersed in an acid solution and connected through a wire, zinc will pass into solution and hydrogen will be liberated at the surface of the iron. At the same time a current of electricity will flow through the wire from iron to zinc.

Fig. 6. Departure of a small coal fleet from Pittsburgh destined for Louisville.

"The principle has been applied successfully to prevent the corrosion of boiler surfaces. The same principle is now being used in the experiments of the Bureau of Mines in an attempt to develop a method for inhibiting the corrosion of steel by acid waters. In these experiments, the electric current is furnished by a storage battery instead of by the solution of zinc and the zinc anode is replaced by one of carbon.

"In preliminary experiments made by Mr. F. M. Stanton of the

Bureau of Mines, two steel plates, 6 by 8 by ⅛ in., one of which was connected in series with a two volt accumulator, and a carbon anode, and the other unprotected, were immersed in the Monongahela River near Lock No. 2, for a period of fifteen days. The loss in weight of the protected plate was 0.7 grams and of the unprotected 10.9 grams.

"Before immersion each plate was carefully polished on one side. At the conclusion of the test it was found that the unprotected plate was corroded and pitted over its entire surface whereas on the protected plate there was no evidence of corrosion.

Arrangements are now being made for experiments on a larger scale and it is hoped that a method may be developed for the protection of steel against the corrosive action of acid waters.

[The following brief biblography was prepared through the courtesy of the Technology Department of the Pittsburgh Carnegie Library.—Editor.]

CHRISTIE, WILLIAM WALLACE. Boiler waters. 235p. 1906.
Rather comprehensive book on boiler waters, including methods of treatment of acid waters for softening.

FLEMING, THOMAS, JR. Chemical apparatus for water purification plants. 4,000w. 1911. (In Journal of the Engineers' Society of Pennsylvania, v. 3, p. 209.)
Considers waters of the Monongahela and Allegheny rivers. Describes apparatus at filtration plants at Charleroi, Monessen, Wilkinsburg and Valley Camp, Pa.
Germicidal effect of mine water and tannery waste. 2,500w. 1910. (In Engineering Record, v. 61, p. 533.)
Information is based on investigations under Dr. Samuel G. Dixon of the Pennsylvania State Department of Health. Indicates that acid condition of river waters is an advantage in destroying typhoid germs, etc.

GRETH, J. C. WILLIAM. Impurities causing scale and corrosion. 2,000w. 1909. (In Boiler Maker, v. 9, p. 115.)
Paper before American Institute of Chemical Engineers.
Indicates the corrosive influence of various salts and acids in boiler feed waters.

HARLOW, JAMES H. Water supply of Pittsburgh and Allegheny City. 3,000w. 1893. (In Proceedings of the Engineers' Society of Western Pennsylvania, v. 9, p. 109.)
Shows the quality of water from the Allegheny river, with analyses. Considers it especially from bacteriological point of view.

LEWIS, SAMUEL JAMES. Quality of water in the upper Ohio river basin and at Erie, Pa. 114 p. 1906. (In United States Geological Survey—Water supply and irrigation paper, No. 161.)

Studies the quality of water in the Allegheny, Monongahela and Youghiogheny rivers and their tributaries. Includes analyses at frequent points.

MOHR, J. A. Acid in Monongahela River Water. 1,000w. 1901. (In Proceedings of the Engineers' Society of Western Pennsylvania, v. 17, p. 237.)

Gives figures showing the acidity of the waters of the Monongahela and Youghiogheny rivers, and briefly considers compounds to be used to counteract the acids.

PATTERSON, D. W. Softening and neutralizing anthracite coal mine water. 22p. 1909. (In Journal of the Engineers' Society of Pennsylvania, v. 1, p. 267.)

Shows the advantages gained in treating mine waters, gives analyses and cost of treatment and includes information from plants in both the hard and the soft coal regions of Pennsylvania, where the acid mine waters are softened.

POTTER, ALEXANDER. Design, construction and operation of the new water softening and filtration plant at McKeesport, Pa. 43p. 1909. (In Journal of the Engineers' Society of Pennsylvania, v. 1, p. 163.)

Full description of successfully operated plant for treating waters of extreme acidity.

POTTER, ALEXANDER. Experience with and results from municipal water softening. 13p. 1910. (In Proceedings of the thirtieth annual convention of the American Water Works Association, p. 236.)

Describes the construction features of the plant at McKeesport, Pa., and shows the acid condition of the Youghiogheny river.

STABLER, HERMAN. Stream pollution by acid-iron wastes; a report based on investigations made at Shelby, Ohio. 36p. 1906. (In United States Geological Survey-Water-supply and irrigation paper, No. 186.)

The same, condensed, 1500w. (In Engineering News, v. 56, p. 543.)

Shows harmful effects of these wastes and their effect on sewage purification processes. Gives method for recovering by-products from waste pickling liquors.

TONNELE, THEODORE, *and others.* The river, well and spring waters of McKeesport, Pa. and vicinity. 2,000w. 1894. (In Proceedings of the Engineers' Society of Western Pennsylvania, v. 10, p. 33.)

Report of committee, with discussion, giving tabulated analyses of water from the Monongahela and Youghiogheny rivers and from shallow and deep wells of the vicinity.

Trax, E. C. The acid waters of Western Pennsylvania. 1,500w. 1910. (In Engineering Record, v. 62, p. 371.)
Condensed from paper before the Central States Water Works Association.
Discusses the extreme acidity of the Monongahela and Youghiogheny rivers especially, and shows the harmful effects of the free acids on fish life, on pumping machinery and plumbing fixtures, and on the quality of the water for drinking purposes.

Water softening and filtration plant at McKeesport, Pa. 3,500w. 1908. (In Engineering Record, v. 58, p. 116.)
Water to be treated is taken from Youghiogheny river into which the acid mine wastes have drained. Describes construction features of a 10,000,000 gallon plant.

Water supply of Allegheny. 15,000w. 1886. (In Proceedings of the Engineers' Society of Western Pennsylvania, v. 3, p. 97.)
Discussion, opened by J. H. Harlow, on the quality of the water in the Allegheny river.

DISCUSSION

Mr. J. R. Campbell:* In discussing the paper of Colonel Roberts, on "Acids in the Monongahela River", it is the natural thing for me, being connected, as I am, with the largest coke producing concern in the Pittsburgh District, to direct attention to the acidity of mine drainage and the part that it contributes towards the contamination of the water supply for domestic and boiler purposes.

Just now we are considering plans and specifications for a purifying and softening plant to be installed on the Monongahela River at Huron, with a capacity of 4 000 000 gallons of water daily and supplying water both for domestic and steam puropses to practically all the Klondyke coke region.

The speaker of the evening has pointed out that it might be a better policy for the "captains of industry" to get their heads together and work out a plan for diverting the contaminating influences, or taking care of them by chemical treatment, instead of spending vast sums of money for the installation and maintenance of mammoth water softeners.

We do not know how such a scheme would work out with other manufacturing concerns contributing towards the pollu-

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tion of the Monongahela River by acids, but at this time I wish to point out that there may be many obstacles in the way of the coal operator, who may naturally desire to follow such a reclamation or purifying scheme, chief of which may be the cost of carrying it out.

For the benefit of any present who are not familiar with the chemical composition of mine drainage, we would call attention to the following analyses, the first two of which represent samples taken from our own coke operations and the third, a sample from an operatin of the Pittsburgh Coal Company:

EXAMPLES OF MINE WATER

	Grains per U. S. gallon		
	L	*S*	*J*
NaCl	1.75	2.59	57.73
Na_2SO_4	13.12	10.34	67.56
$CaSO_4$	86.30	32.05	77.28
$MgSO_4$	56.54	22.09	18.29
SiO_2	2.10	2.33	1.52
$Fe_2O_3+Al_2O_3$	.....	51.54	.....
Fe_2O_3	12.07	.....	45.50
FeO	72.53	16.50	not det.
Al_2O_3	6.65	.....	116.05
SO_3	93.23	93.44	SO_3
H_2SO_4 (free)	26.30	213.50	1013.46

Note: The figure 1013.46 in *J* is the SO_3 that is both free and combined with the iron, the greater portion being free SO_3.

WATER PUMPED DAILY

	L		*S*
Maximum	1,500,000		15,000,000
Minimum	750,000		5,000,000
Free SO_3 (Min.)	1 ton	(Max.)	180 tons
CaO for neutralizing SO_3	.7		126 tons
Cost per day	$3.50		$630.00

OTHER OPERATIONS

	Free SO_3 in Grs. per U. S. gallon
D. Fce. Co.	114.303
B.	172.622
L. No. 1 (a) clear	100.307
(b) red	132.965
L. No. 3	243.494
V.	201.901
S.	501.970

All present are perhaps familiar with the origin of "free acid" in mine drainage, i. e., the oxidation of the iron pyrites (FeS_2) in coal by means of air and water through the various stages of ferrous sulphate, ferric sulphate, etc., until the acid radical is entirely free, forming the "free acid", which gets to be of enormous proportions in the case of an old mine working.

We wish to point out in the case of the examples cited, some of the commercial aspects of the question of mine drainage. We will not consider sample *J* since it is an old and an abandoned working. In samples *L* and *S* there are 26.3 and 213.5 grains of sulphuric acid, respectively, and taking the minimum pumpage daily at mine *L*, with the minimum acid in it, and the maximum pumpage at mine *S* with the maximum acid in it, we have some very interesting figures.

In the first case we find that there is discharged in 24 hours one ton of free SO_3 and in the second case 180 tons of free SO_3 in the same time. This would perhaps represent the maximum and minimum of any condition we might have.

Obviously, the simplest and cheapest method of chemical treatment is to neutralize the "free acid" with lime, which we have taken at a cost of $5.00 per ton. In the case of mine *L* the daily cost of neutralizing the "free acid" would be $3.50 and in mine *S* $630.00. The increased cost per ton of finished product at the above rates is 3½ mills per ton in the case of mine *L*, and 30 cts. per ton in the case of mine *S*, which, in these days of close competition, would almost put a concern out of business in the last case cited.

There is another phase of this drainage problem to which attention has not been directed very strongly, and that is the possibilities of the water as a source of iron oxide for the manufacture of Venetian red and other paint pigments. We have made some experiments along this line in our laboratory, and have made iron oxide paint from sulphur mud, which has been pronounced to be as fine as anything on the market, if properly calcined and ground.

In this connection, we direct attention to the following tabulations:

IRON OXIDE IN MINE WATER

C No. 1	.14%
R	.14%
Sh	.08%
Bore hole	.11%
Shaft	.12%

CHEMICAL ANALYSIS OF SULPHUR MUD AND PIGMENT

		Sul. Mud	*Heck. Paint*	*Paint*
	Wet	*Dry*	*Dry*	*Dry*
SO_3		13.07	2.22	nil
SiO_2		.49	3.29	.36
Al_2O_3		.17	.34	.19
CaO		trace	1.04	.51
MgO		trace	trace	.09
Fe_2O_3		62.01	89.06	94.86
MnO_2		.04	.23	.....
P_2O_5		1.44	.42	2.29
Loss		(H_2O) 23.24	(H_2O) 2.90	2.30
Alkalies		.51	.50	H_2O+SO_3
Moisture	86.85			

In the first tabulation the maximum amount of iron oxide in mine water is 80 grains per gallon. Assuming the volumes of water pumped in mine *L* and mine *S*, there is wasted daily in the first case 4¼ tons of iron oxide and in the second case 85 tons of iron oxide. The finished product has a market value of $60.00 per ton. Assuming this figure in our calculation, we have $250.00 worth of iron oxide paint pigment in the daily pumpage of mine *L* and the enormous value of $5000.00 worth of first class Venetian red in mine *S*. In a jocular vein, there is enough iron oxide wasted daily in the mine drainage of operations in the Connellsville region alone to paint "the town red",—even the city of Pittsburgh with its dark back ground of soot and smoke deposits.

But so far as we know, there has been no practical method found for separating the iron oxide from mine water, even though it precipitates readily by the addition of heat, or the proper chemical. We know of one concern who is willing to buy sulphur mud, such as is found along water courses, sumps and gob sections where it often deposits to the depth of several feet. This concern has offered us as high as $4.00 a ton for sul-

phur mud, or the deposit from mine water, even when badly contaminated with impurities. By referring to the analyses of this raw and finished material, it will be noted that the iron oxide content is very high, ranging up to 95 percent.

It may be that the time will come when the iron oxide in mine water will come to be a very valuable by-product and that operators can then afford to neutralize the "free acid" at the same time recovery of the paint pigment is made, which would be a happy solution of the problem.

Mr. R. B. Dole:* In complementing Colonel Roberts' excellent presentation of the troubles caused by acid wastes I wish to call attention to a few figures showing the extent of the pollution and the necessary magnitude of any plans to abate it. These

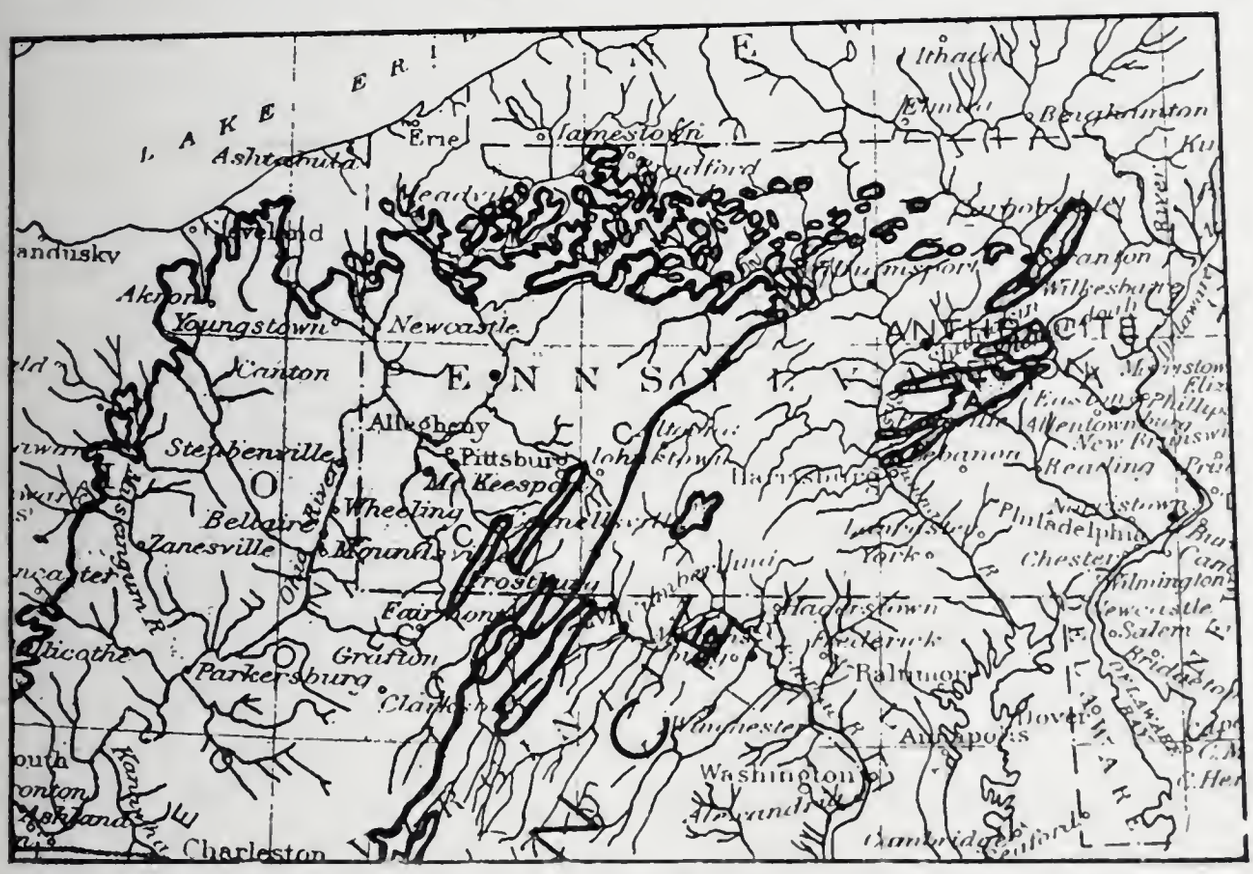

Fig. 7. Map showing location of Coal Fields in relation to Drainage in Pennsylvania and the immediate vicinity.

figures prove that the question of mine drainage far exceeds in importance the question of pickling liquors from galvanizing works and similar manufactories.

The shaded portions of Fig. 7 indicate the areas of coal according to reports of the United States Geological Survey. These coal veins and the contiguous layers contain sulphur in

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several forms, possibly the most important of which in this connection are the sulphides of iron, which, becoming oxidized, form sulphuric acid that is in turn capable of dissolving iron and other bases, thus forming sulphates in solution. Without going into the theoretical reactions it may be said that an excess of free sulphuric acid is nearly always left and consequently free sulphuric acid exists in the drainage from the mines to the streams. When the corrosive solution reaches the streams it decomposes the carbonates and bicarbonates in the river waters, replacing them by sulphates. If there is enough sulphuric acid to exceed the weaker acid radicles, free sulphuric acid exists in the main stream. If not, the sulphates are increased at the expense of the carbonates, but the river water is still slightly alkaline. This disturbance of the percentages of carbonates and sulphates in the mineral residues obtained by evaporating the river waters to dryness affords a basis for estimating the extent of the sulphuric acid pollution.

For making such comparison it is absolutely necessary to have long-term records both of quality and of flow of water, and such data have been obtained by the Water Resources Branch of the Geological Survey. In 1906 and 1907 daily samples of water were collected at each one of the places indicated by the black dots in Fig. 7. The daily samples were united in sets of ten consecutive samples, and analyses were then made of the composites thus obtained. The collection was continued for a year, so that records now exist from which the average quality of the river water at each of these stations may be computed. The following table shows the composition of the mineral matter in the principal rivers within or near Pennsylvania as computed from these analyses. The figures have been rounded off to whole numbers for simplicity and the percentages only of the principal ingredients are given. The last line of the table, showing what the composition of all the waters probably would be if they were in the normal, or unpolluted, state has been computed from a large number of tests. It may be noted how closely the percentages of the bases agree. The percentages of chlorine agree well except that of the Allegheny River, which differs because that stream receives salt water pumped from oil wells.

But wherever mine drainage in any considerable quantity reaches the stream the percentage of sulphates is increased and the percentage of carbonates is decreased.

ABNORMAL CONDITION OF SOME RIVER WATERS

River	*Station*	*Percentage of Residue*							
		SiO_2	Ca	Mg	Na	CO_3	SO_4	Cl	T.S.
Allegheny	Kittanning	9	16	4	13	22	20	16	87
Monongahela	Elizabeth	11	16	3	9	12	43	4	81
Youghiogheny	McKeesport	5	13	4	5	0	68	2	197
Potomac	Cumberland	6	19	4	7	14	45	5	130
Lehigh	So. Bethlehem	9	15	6	8	21	32	5	95
Delaware	Lambertville	13	18	5	8	33	18	4	70
Shenandoah	Millville	11	23	6	5	47	4	2	140
Susquehanna	West Pittston	11	20	4	7	35	16	5	90
Susquehanna	Williamsport	10	16	5	8	19	35	5	74
Susquehanna	Danville	8	19	4	8	24	28	7	112
Normal		9	18	4	8	38	17	4	...

Total solids (T. S.) in parts per million. The percentages are rounded off to whole numbers for simplicity.

This marked change coupled with the concurrent uniformity of the bases is obviously due to decomposition of carbonates by sulphuric acid. And this difference in sulphates can be combined with the discharges of the streams, which have been determined by the Survey for long periods, to obtain an estimate of the total amount of sulphuric acid wasted in mine drainage. For example, the excess of sulphates in the water of Susquehanna River at Danville is eleven percent of the residue, or 12 parts per million; the mean discharge of the stream is 1.71† second-feet per square mile of area, and the area above Danville is 11 070 square miles. It is a simple arithmetical problem then to calculate that the excess of sulphates represents 240 000 tons a year of 66 deg. Beaume sulphuric acid. Similar computations for the other Pennsylvania streams in the accompanying table give a total of 970 000 tons a year of acid. In other words the sulphur in the coal in the drainage basins of these few streams produces annually more than half as much sulphuric acid as the listed production of the entire United States. When we consider that this large figure represents only

†Water-Supply Paper U. S. Geological Survey 234, 1909.

26 000 square miles of territory we can readily believe that the total production of acid from the mines of Pennsylvania is not less than a million and a half tons a year. All this acid does not exist in the streams in the free state nor does it reach the streams always in the free state, for part of it forms soluble salts with iron, limestone, and other substances and thus becomes partly neutralized. But the figure represents the magnitude of the original production of acid from the sulphur in the coal.

Now let us consider what this great quantity means in connection with any plan that may be proposed for abating the pollution. Let us assume, for example, that legal prohibition prevents the discharge of free acid into the streams and that as a consequence it is proposed to neutralize the acid with limestone, the cheapest source of bases. Not all of the million and a half tons of acid has to be neutralized for most of it becomes combined before it reaches the main streams; but an extremely conservative estimate of the free acid would be ten percent, or 150 000 tons. Several of the analyses that have been quoted here tonight indicate that ten percent is far too low. Now the neutralization of even this small proportion of ten percent would require the annual solution and destruction of 170 000 tons of limestone containing 36 percent of carbonates expressed as CO_2, which is the average content of building limestones. If the limestone were used in trickling filters or contact beds at least 20 or 30 times as much rock as that required for solution would have to be put into place in order to provide space and surface for rapid passage of the liquid. Thus it can readily be seen that while compulsory treatment of the waste before it reaches the streams is not absolutely out of the question it is not at all a small problem or one that can be solved without enormous expense.

There is another side to the problem also. The limestone would go into solution and thereby increase the scale forming constituents of the water. Therefore, though use of soda ash to neutralize free acid would be obviated, the quantity of soda ash required to remove the hard-scale forming ingredients would be increased, so that the ultimate cost of chemicals for treating the water before boiler use would not be lessened.

The examination of water from Youghiogheny River, a typical acid stream, afford evidence of how great the pollution is and also of how much it varies in its effect. The accompanying diagram, Fig. 8, represents the results of tests of water from this stream at Versailles near McKeesport. The upper dash line represents the total amounts of sulphates in the water; the heavy solid line below it represents the amount of free sulphuric acid; the lowest line gives the daily gage heights as reported by the Weather Bureau for the gage at West Newton, ten miles above Versailles, and the dotted line just above represents the same gage heights reduced to ten-day periods coincident with the sampling periods. A glance at this diagram is sufficient to prove the absolute unreliability of any estimates of average conditions from the results of analyses of one or even three or four, spot samples. Normally the water is acid, but when gage height goes up the acidity goes down. In fact when the floods are great enough, that is, when the quantity of alkaline water in the stream is sufficient, the acid is completely neutralized and the water contains carbonates. The shaded points on the free acid curve indicate periods when the water was alkaline. Between March 10 and April 14, 1907, for example, the conditions changed in ten-day periods from 7.5 parts per million of bicarbonates to 66 parts per million of acidity, expressed as $H_2 SO_4$.

The diagram shows this relation. A relatively constant quantity of sulphuric acid enters a stream that fluctuates greatly in discharge and that contains carbonates, which are wholly or partly destroyed by the acid. The relation suggests a compromise course that might prove to be feasible in preventing the continuance of acid rivers. Namely, not the complete neutralization of the acid in the drainage but the reduction of it to such quantity that the carbonates present in the minimum flow of the stream would take care of the remainder.

The enormous quantity of this waste and its commercial value in concentrated form might well bring it into attention as a research problem for industrial chemists. During the year that samples were collected the water of Youghiogheny River averaged 22 parts per million of free acid. As the average discharge of the stream is about 2.3 second-feet per square mile of

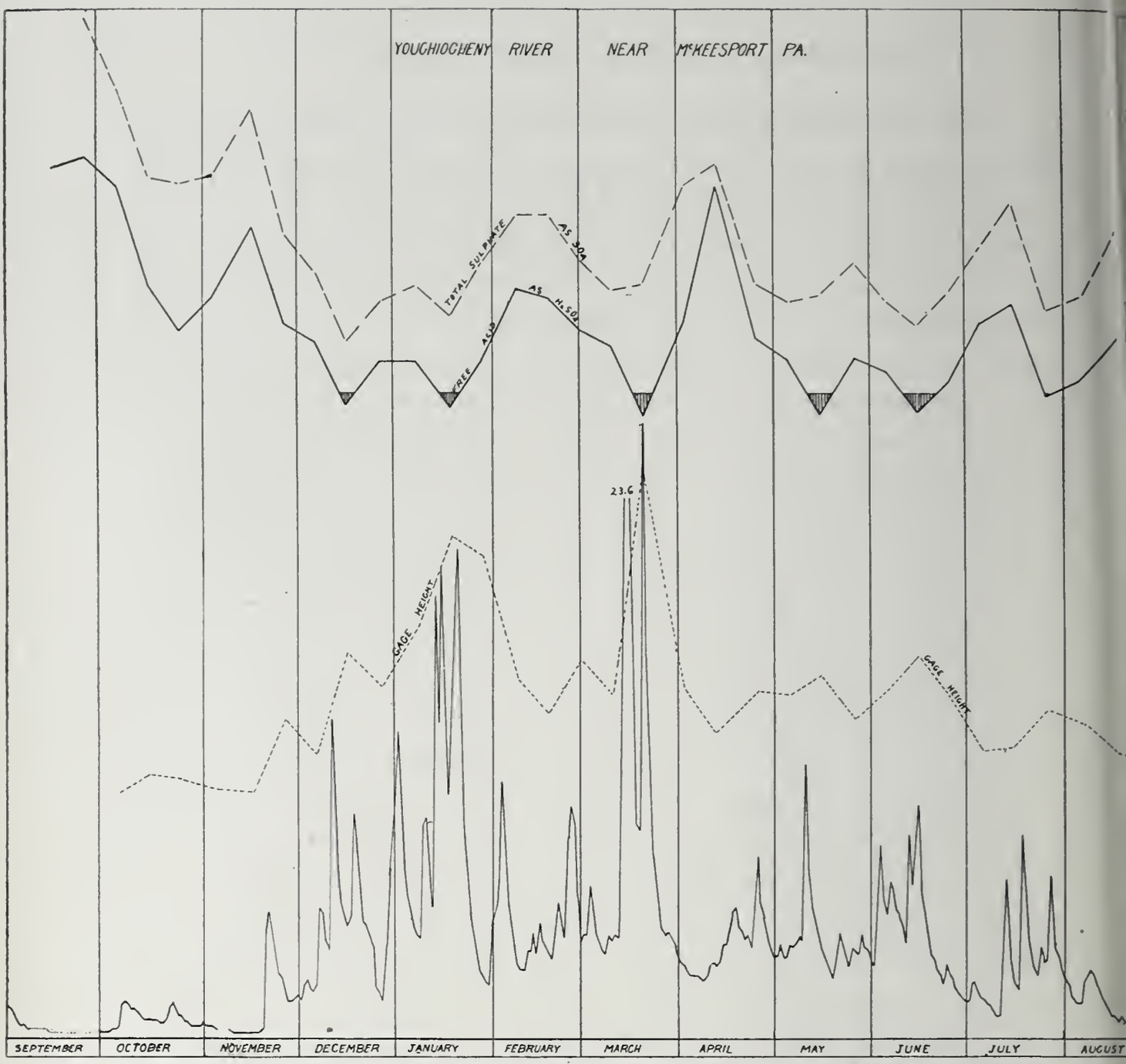

Fig. 8. Acid conditions in the Youghiogheny River near McKeesport, Pa.

drainage area, it can easily be calculated that 95 000 tons per annum of 66 deg. Beaume acid pass this place every year—a product worth not less than $1 200 000. The apparent bars to the economical utilization of this material are its extreme dilution and its fluctuation in concentration. It might, however, be caught in more concentrated state at its issuance from the coal beds; one speaker tonight has mentioned the value of the ferric oxide that could be obtained as a by-product, and it does not seem without the bounds of possibility that processes of recovery might be found. It is worthy of note that in a neighborhood where nearly a hundred thousand tons a year of acid are consumed in factories, one stream carries away every year more than a million dollars' worth of acid produced by Nature.

Mr. W. E. Snyder:* In reading over this paper it seems to me there are several points in it which require some further explanation, or elucidation. Because of Col. Roberts' long connection with work on the Monongahela River, any statement which he makes regarding the river water, will be properly accepted as authoritative. On this account it is of special importance that the facts regarding certain points which are raised in the paper, should be clearly known so far as they are available, in order that no incorrect inference may be drawn from some of the general statements contained in the paper.

The condition of the water is bad, there is no doubt about that. One of the objects of the paper is to endeavor to make some estimate of the quantity of acid which actually passes a certain section of the river per day of 24 hours, in order to give some conception of how bad the water is. This is not of very great importance, because the tonnage of acid which passes a certain section of the river per day should only be considered in connection with the total volume of water which passes the same section per day. In other words, it is the proportion of the weight of acid and acid salts to the total weight of water passing a given section which is the true indication of the harmful properties of the water. Even when this is obtained, it does not do us very much good, as the principal questions are, where does the acid come from and what should be done to prevent the conditions which exist.

In regard to the source of the acid that is found in the river, the paper contains considerable discussion relating to the sins of various steel works on the river. It is of this particular phase of the subject that I wish to speak, as I think too much emphasis is laid on the quantity of acid discharged into the river from the mills, and not enough emphasis on the quantity which comes from mines. However, the statement is made that the investigations of one of the United States engineers connected with the Pittsburgh office show that much the larger proportion of the sulphuric acid reaching the river comes from the coal mines. This is followed by an estimate of the quantity which is supposed

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to reach the river from the steel works, and the inference that is apt to be drawn is that both these classes of offenders can be mentioned in the same breath, whereas the fact is, they should not be mentioned in the same week,—there is such a wide discrepancy between the effect produced on the character of the water by all the acid discharged from the mines as compared to the effect produced by the acid discharged from all the mills. As illustrating this point consider the following facts. The American Steel & Wire Company operates three plants on the Monongahela River which use acid in the process of manufacturing. Two of these plants are what would be regarded as large consumers, and the other one moderately large. During 1910 these three plants consumed 8000 tons of sulphuric acid and 3000 tons of muriatic acid, an average of 3667 tons per works per year. The paper mentions that there are twelve such establishments on the Monongahela River or its tributaries. I do not have any information covering the quantity of acid consumed by the other plants, but assuming that the above average will hold for all of the plants, the total quantity of acid used by the twelve mills per year is not over 50 000 tons.

If we take the above figure as the quantity used per year, and also the figure given in the paper of two percent for wastage, there are 1000 tons of free acid wasted in the river per year, and assuming that this occurs in 300 working days, there would be $3\frac{1}{3}$ tons of free acid wasted per day. The paper estimates that the river carries an average of $64\frac{1}{2}$ tons of acid per day past a given point, and according to the figures which I have just stated, $3\frac{1}{3}$ tons of this comes from the mills, or about five percent of the acid in the river comes from the mills and 95 percent from the mines.

One point that I wish to mention particularly in connection with the acid that I have mentioned above as being used at our works, is that approximately 27 percent of the total quantity is muriatic acid, the remainder sulphuric. It is probable that other manufacturing plants use muratic acid also, yet in all the investigation that I have ever made of this matter, and in the much more extended investigations of others who have had more to do with the purification of water, I have never heard of any

analysis reporting free muriatic acid. It is always the sulphuric acid which is found, and which causes the complaint. If the waste discharge from the mills was producing any appreciable pollution of the water, muriatic acid would certainly be found the same as sulphuric, except of course in smaller quantities.

However, this still does not enable us to look at the matter in its proper perspective. I have stated above that the three works with which I am familiar, use in round figures 11 000 tons of both kinds of acid. The spent liquor from 4000 tons of this acid was used in the manufacture of sulphate of iron in a plant for this purpose at one of the works mentioned. This leaves the liquor from 7000 tons of acid which reached the river during 1910. The sulphate of iron plant was installed with sufficient capacity to utilize practically all the sulphate liquor that is produced at all of our works on the river, and arrangements are now being effected whereby this liquor will be shipped from the respective works where it is produced, to the sulphate plant, where it will be utilized. This is one example of what is being done by the manufacturers to eliminate the small proportion of the river pollution which comes from the works that are mentioned in the paper. A discussion of the steps that are in progress to eliminate the pollution that comes from coal mines will be of great interest in the further development of the paper under discussion.

As indicative of just what results are produced by the mines, I can quote actual data from one mine. The quantity of water discharged from this mine is 100 000 gallons per hour. Actual analysis of this water gives 59 grains of free sulphuric acid per gallon and 135 grains of ferric sulphate per gallon, which so far as its effect on water for boiler feed purposes is concerned, is as bad as the free sulphuric acid; or by leaving out of consideration for the present the ferric sulphate, the free acid discharged into the river from this one mine is something over 4000 tons per year, while if the ferric sulphate be also considered, this quantity must be multiplied by 3.3 in order to get the total quantity of polluting matter that reaches the river from this mine. In other words, there was discharged in 1910 from this mine, a very much larger quantity of polluting matter

than was discharged from the three manufacturing plants which I have mentioned.

I do not want to be understood from the above as defending, or condoning the pollution of streams by manufacturing plants. I have absolutely no such intention in mind. What I wish to point out and emphasize, is the comparatively small percentage of pollution which results from manufacturing establishments, and also that at least some of these establishments are taking active steps to stop even the comparatively small pollution which does occur now from the waste liquor. The problem is not how foolish the manufacturers are at present for dumping waste liquor into the river, from which they must pump water for boiler feeding; it is what means can be adopted to prevent the pollution of water by the drainage from all the coal mines on the entire water shed. If every manufacturer on the river were to stop completely the discharge of waste liquor into the river, those who use water from the river for manufacturing purposes would never know it,—if their getting the information depended on the reduction of average acidity of the water. Another point is, the manufacturer has solved the problem of the prevention of pollution, by manufacturing the waste liquor into iron sulphate, a commercial product. So far as I know, there has been no practical method as yet put into use for the prevention of pollution from coal mines. On account of the wide discrepancy which exists between the harm produced by the pollution from coal mines and that produced from the manufacturing plants, it would seem to me that an investigation would be very much in order to determine what practical means, if any, could be adopted to prevent the pollution of the river by the coal mines located on its water shed. In this investigation no mention whatever need be made of manufacturing plants, as the proportion of the harm which results from their operation is so small compared to the total damage; also as they have already developed a means for prevention, such plants would have no place in this kind of an investigation.

Another point in this paper to which I wish to give some attention is that of the installation and operation of water purifying plants by manufacturing establishments. The inference

that can be drawn from the author's discussion of this subject is that the installation of water purifying plants causes a very heavy expense to the manufacturer, and is only done because of the acid condition of the river. I can best explain this by giving some information in connection with the practice in our own Company. Our Company operates seven water purifying plants in as many different works. These seven purifying plants have an hourly capacity of 330 000 gallons. Three of these plants, or 35 percent of the total capacity, are located on the Monongahela River. The other four, or 65 percent of the total capacity, are located on rivers where there is no acid at all; one in eastern Pennsylvania, two in Ohio and one in Indiana. They are regarded with as much favor and considered practically as necessary to the operation of the works with which they are connected at all of the latter places as they are on the Monongahela River. The fact is that water purifying plant is put in to *purify* the water, not to neutralize the acid that is in the water. This is one of the necessary steps in the process if the water that is treated contains acid, but it is by no means the only step. It so happens that in the Monongahela River the acid in the water makes this step an improrrtant one in its treatment, but it is also very strongly probable that many of the manufacturing works would have their water purifying plants just the same if there were no acid in the river. The purpose of treating water for boiler feed is to neutralize acid when it is present; to eliminate the scale forming matter so far as is possible, and to remove all suspended matter, either by settling or filtering or both. It is, therefore, not strictly correct to charge the installation of water purifying plants on the Monongahela River to the acid pollution of its water.

I am too much of a lover of nature and of all kinds of wild life to close this discussion without some reference to the esthetic side which has been incidentally mentioned in the paper; i. e., the harmful effect of the pollution of the water upon all kinds of fish life that is found in rivers having pure water, but again I would call attention to the effect of the mine water on streams on which there are no manufacturing plants whatever. There are numbers of small streams in this section of the State on

whose water sheds there are no manufacturing plants, and yet all kinds of life has practically vanished from the waters of these streams after the opening of coal mines on their water sheds. With the disappearance of the life in the water, there also goes a great deal of the wild life along the water, which is absolutely necessary to complete the natural beauty of any stream in the country. When the fish and small reptiles of a contaminated stream disappear, the water birds and small animals which depend for their food supply principally on the stream, must also disappear. The waters of the river and larger streams flowing into it would not only make a substantial contribution to the food supply because of the fish which they would produce, but because of the fish life which they contain they promote bird and animal life on the adjacent land. All of this together combines to give many people pleasure and profit in many ways in the out-of-door life which it fosters. All of this vanishes when the stream becomes contaminated by mine discharge. This is, of course, apart from any discussion of the damage which acid in the water does on pipes, boilers, etc., but it has both a utilitarian and an esthetic value which cannot be ignored in any discussion of this kind, though it often is overlooked by a large proportion of the American people.

A short time ago a paper was read before the Mechanical Section of this Society on Smoke Abatement. This paper deals with the pollution of river water, and I have shown that nearly all of this pollution occurs because of the large quantity of mine water that finds its way to the river. The reputation of Pittsburgh coal as a steam and gas coal is known all over this country. It is evident that the location of a large manufacturing district such as this in the midst of such a rich coal field is not without disadvantages. Mining and using Pittsburgh coal evidently levies an assessment on all the people of this District, whether they know it or not.

Mr. E. C. Trax:* The paper of the evening is a valuable addition to the literature of this subject, the importance of which is fast becoming realized. The increasingly large amount of free sulphuric acid and sulphate of iron in the streams of this

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district is indeed becoming a serious problem. The experience of the city of McKeesport with acid water, previous to the installation of the treating plant, is pretty well known; the fact that brass valves are rapidly eaten away, and even the "acid proof" bronze impellers of centrifugal pumps affected to some extent, indicates the corrosive action of the Youghiogheny River water. Engineers from other sections of the country are appalled when the condition of this stream is brought to their attention. During 1910 a new mark was set for extreme acidity; on October 30th the acidity to phenol-phthalein was 35 grains per gallon, and to methyl orange, which is a close approximation of the free sulphuric acid, 23 grains per gallon.

The disadvantages of the acid in relation to water purification for domestic purposes are generally summed up by high cost of treatment; this includes the necessity for more expensive construction of treating plants, high cost of chemicals, additional expense of labor for handling chemicals, wear and tear on machinery, etc. The purification of water containing acid iron wastes presents no special difficulty, except that of cost. There are, indeed, several features which have even been considered slight advantages, although they might well be overlooked in comparison to the array of injurious effects. When the acidity is very low, amounting to 0.2 to 0.3 grains per gallon, there is present in the water, ordinarily, a sufficient amount of the sulphates of iron and aluminum to thoroughly coagulate it, so that with the usual type of mechaincal filtration plant, it is necessary to supply a little lime only to obtain perfect clarification. Following a rain on the watershed the Youghiogheny remains in this condition for a day or two, but soon reverts to what may be called its normal condition—that of very high acidity and ferrous sulphate content. Occasionally the water comes from the river thoroughly coagulated and clarifies rapidly without any treatment whatever.

At some points in the Monongahela this condition of slight acidity prevails for longer periods and water purification plants may be operated for several months of the year without the use of iron or alum.

Another effect which has been pointed out as beneficial is is the germicidal action of the acid and iron salts. According to experiments made by the Department of Health of Pennsylvania, the growth of the typhoid bacillus is prevented after exposure to mine water for one hour, and the growth of the colon bacillus materially limited after a somewhat longer time. For this reason the advisability of excluding acid drainage from streams which may become sources of drinking water, is seriously questioned.

The following table of monthly averages of acidity and number of bacteria in the Youghiogheny River at McKeesport, shows the effect of the varying acidity on the germ life:

Month	Av. Acidity (a) Grs. per gallon	Bacteria per cubic centimeter. (b) 24 hrs. incub. at 37 deg. Cent.	48 hrs. incub. at 20 deg. Cent.
Jan.	0.64	576	31 000
Feb.	2.16	105	20 000
Mar.	2.10	2000	21 000
Apr.	3.03	446	12 000
May	1.34	178	2 000
June	0.35	681	6 500
July	3.79	167	205
Aug.	10.62	65	9
Sept.	6.59	682	97
Oct.	14.00	300	240
Nov.	10.27	416	160
Dec.	1.69	98	2 400

(a) Acidity to methyl orange. Average of three to eight determinations made each day.
(b) Average of daily determinations.

The apparent slight effect on the body temperature organisms is explained by the fact that raw sewage is discharged into the river less than a mile above the water works intake, so that the bacteria present in this sewage are not exposed to the acid for a sufficient length of time to cause their destruction. The situation along the Monongahela is similar; sewage reaches the river at numerous points, and may be pumped out for use as drinking water before sufficient time has elapsed for the removal of disease producing bacteria, which may be present. It must also be taken into consideration that water containing a suffi-

cient amount of acid-iron waste to materially reduce the bacteria is unfit for use as a domestic supply on account of the taste, corrosive action, and presence of iron, which alone renders it unsuitable for laundry purposes. The credit for preventing typhoid is not very apparent in the cases of McKeesport, using raw Youghiogheny River water, and the Borough of Braddock, using Monongahela River water, during the years of 1906, 1907 and 1908. The average yearly death rate from this disease in McKeesport, during this period was 86.5 deaths per 100 000 population, and for Braddock 98 per 100 000. These figures are far in excess of the state rate of 34.6, and the rate for Pittsburgh, which was 46.6. Some of the typhoid in McKeesport, and undoubtedly in Braddock also could be traced to drinking well water, but if the municipal supply of dilute sulphuric acid becomes so unpalatable that the residents are driven to the use of well water, and contract typhoid therefrom, the city supply is just as surely to blame as though the disease germ is present.

Treatment of the acid wastes with lime before discharging them into the water courses, which is the cheapest method of neutralization, would furnish relief from corrosion troubles, but would increase the calcium sulphate to such an extent that softening for boiler purposes and domestic supply would be almost as imperative as it is at present.

Mr. J. N. Chester‡: It is getting late and I do not know that any one so unprepared as I has any right to occupy time. It seems to me this question resolves itself into the greatest good for the greatest number. I believe if we could look into the purpose of our Creator in giving us the streams, we would find they were primarily put there for drainage purposes, and that is the first benefit creation got from them. The next thing was as a water supply, and probably after that came means of transportation. The initial paper tonight would protect navigation to the exclusion probably of everything else. Constituted as many of our bodies are that have charge of the streams, there seems to be foregathering a conflict of authority. Already we have the navigable streams in charge of the War Department

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and primarily the United States engineers. In this state we have the purity of the streams to a certain extent guarded by the State Board of Health, and we have still another authority looking after the streams to a certain extent in the way of the State Water Commission. In these three bodies there is a conflict of interests. It seems to me that we must come back finally to something in the shape of Senator Newlands' bill which puts all water ways in the hands of one Commission to administer and controls them for the greatest good to the greatest number, and I believe when this is done, the question of whether or not we can permit mine and mill waste and sewage from cities to interfere with navigation, or navigation to interfere with water supply, or water supply to interfere with commerce and industry, will all be taken up and settled. But it will be a good many years before we arrive at that point.

The author of the paper tonight, interested as he is largely in navigation, looks at the question from that view point. Interested as we are in water supply and sewage disposal, we are bumping up against the engineers' department where navigation must have precedence, until we sometimes think that navigation is getting a little the best of it.

If we are going to preserve the streams from one thing we must of course preserve them from another. Most of you are familiar with the Massachusetts plan, where, if I understand their conditions aright, they have there separated their streams into what they call sewers and water supplies. There are three streams, the Connecticut flowing entirely through the state, the Merrimac, rising in another state, and the Blackstone, a large stream south of Boston. The first two streams for all, and the latter for a certain part of its course, are called sewers, and into these streams cities and factories may pour about anything they choose, but the tributaries of these streams must be kept clear, and are characterized as water supplies. If we are going to purify the streams in the Commonwealth of Pennsylvania, we are going to make a big investment and create a very large engineering and chemical problem.

More than five years ago I made the statement that for cost of purifying the sewage of the city of Pittsburgh, and the in-

vestment necessary to change the sewers I would furnish every city between here and Cincinnati with good water supply and have some money left. I am of the same opinion still and the same may apply to the keeping the acids out of our streams. The case has been presented tonight much more directly and clearly than I could state it, and, if it is as clear to you as it is to me, to neutralize the acids that are poured in from the coal mines alone would create an expense that would put the cost of living in the way of coal where there would be a wail and probably the vote of the people, if the privilege were given them, would call for putting the acid back into the river and give them cheaper coal. I wish to emphasize again that you all read Senator Newlands' bill and think of it in this light, the light of the control of these streams in one body that will harmonize the interests of the people and not try to put the interest of one ahead of another.

Mr. Morris Knowles*: The Society is again indebted to Col. Roberts, as it has been so frequently before, for so interesting and timely a paper. The author states his principal object is to promote efforts to mitigate the evils resulting from the unrestricted deposit of acid wastes in streams. He has certainly provoked a discussion, which indicates a desire to place the blame upon "the other fellow."

There are several topics suggested by the paper which the speaker will briefly discuss, in the order as they occur to mind, remembering the suggested outline in the advance notice for this meeting.

Possible Benefits due to Acids: It has been stated by the author that the acid has some sterilization and clarification effect upon the river water. It seems to be a somewhat popular notion that the benefit of this action may be relied upon to the exclusion of other well known remedies for bad water. It is true that an acid condition of water will destroy organic and bacterial life and thus render the use of such water less harmful from the hygienic standpoint at this time. It has been noticed in recent years, even before the introduction of filtered water upon the South Side, that at certain times when the Mononga-

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hela was low and acid, the bacterial content of the water was much less than would naturally be expected from the large amount of sewage received from the populated territory above It is even stated that typhoid fever was less prevalent upon the South Side than in the remainder of the city. It is possible that some of the improvement effected may be due to the extensive heating of a portion of water in the various steel mills and return of this amount to the river in a sterile condition.

The effect of an acid water upon a turbid stream and the marked clarification which results has been described in the paper. Neither the sterilization nor the clarification which is due to the presence of acid wastes in a river water can be depended upon to safeguard the public health. One can never tell whether either of these effects will be obtained at any given time. In any water improvement system uniform action is absolutely necessary and reliance should not be placed upon any phenomena which may or may not occur.

Injurious Effects of Acid: The two effects mentioned may really be a positive menace to health. Where their action is depended upon, there may be over confidence at times of high water, when the acid content is insufficient to produce sterilization. Such a period will be followed by a marked increase in disease and in death. This effect has been observed upon the South Side at times other than when low water was prevalent.

The acid conditions also seriously interfere with the operation of water softening plants. Mr. Snyder has truthfully stated that such systems would be necessary in the majority of industrial establishments in this vicinity, irrespective of the acid condition of the streams and on account of the lime and magnesia salts. On the other hand, the acid, with its rapidly changing amounts produces another complication, one that is sometimes very trying and greatly increases the cost of treatment.

It has been found that an acid condition of the Allegheny River may destroy the bacterial film on the surface of a slow sand filter; thus permitting the water to pass through the filter more rapidly than it should and without successfully purifying. The important function of the principal feature of the filter

is therefore rendered non-effective, so that dependence upon that which is expected to safeguard health is useless; again we see the acid condition of our streams is really injurious.

Amounts of Acid: In the desire to put the blame upon "the other fellow" several speakers have contributed much information as to what is really being done. The speaker has been very much interested in the statements regarding the output of drainage from a few mines of this region, which may conservatively be taken at an average of 1 000 000 gallons per day for each one. When one remembers that there are over 1 000 mines in the region drained by the Monongahela and Allegheny Rivers, the suggestion of a billion gallons per day, or even half of that, shows that the mine drainage must be the source of the universal trouble resulting from the presence of acid water in the rivers. The probable intensity of a large acid output from pickling works has wisely been mentioned by the author, as really capable of producing more damage upon the boat which is tied up nearby, than the less concentrated acid water from other sources. Such plants, however, do not increase the general acid content of rivers to a marked degree. Regarding mine drainage: In probable recognition of the importance of the industry, the Purity of Waters Act of 1905, in Section 4, states that the provisions do not refer to waters pumped or flowing from mines, or from tanneries.

The author's reference to the thought that the Ashoken aqueduct of New York City would not furnish sufficient pure water to manufacturing concerns along the Monongahela River, is possibly slightly in error. The capacity of the aqueduct, which is 500 000 000 gallons per day, certainly seems in excess of the amount of water required by all the mills in this vicinity. However, it would certainly be easier and cheaper to supply even this enormous quantity of water to the mills than to collect all the drainage from the various mines and convey the acid water into the river below the factories and to a stream with greater dilution.

Referring again to the laws. The Act of Congress, which the author quotes, is an example of vague and indefinite legislation. It will be interesting to know whether any suit has ever

been brought under the terms of this act. It apparently does not preclude liquids nor that which flows from streets and sewers. What would happen if any kind of debris should pass from the streets of a mining settlement; or any kind of factory waste, solid or liquid, should first be emptied into town sewers before passing into the river? Would the act then be effective in any of its provisions?

Possible Benefits from Storage Reservoirs: It is hard to understand the author's statement in which he concludes that storage reservoirs would be of little avail. He grants that there may be some slight effect in diluting the acid to a safely usable point. If this be so, why would it not a greater benefit if there were greater storage and thus increased low water flow, with the accompanying greater dilution? It certainly seems somewhat far fetched and difficult to perceive that such increase of smallest flow would materially increase the cost of navigation and the operation of locks. It would be of much interest and help to have the author discuss this point in greater detail.

Investigations: It appears that the most important thought which can be obtained from the paper is that the time is now ripe to thoroughly study this perplexing subject. We all realize that the presence of acid in the streams is injurious and harmful, even in a diluted condition. There are few data of a concordant kind relative to the variations in acid content with the height of stream and the volume of flow. A great deal of good would result if all of this information were collated and brought together in one complete statement.

Some years ago the speaker had the good fortune to discuss another important paper by Col. Roberts relating to floods; of which he stated, because of the lack of complete data, that we should have a thorough investigation, in order to better understand the situation. It is gratifying to know that shortly thereafter the Pittsburgh Flood Commission was created by the Chamber of Commerce and we are soon to have a complete report upon this very important subject, in which all the data, local, national and foreign have been brought together for our study.

The Department of Health of this state has not considered it necessary to be paternal, to the extent of making extensive studies and experiments and conducting a campaign of public education along health lines. When the Act of 1905 was passed, much pioneer investigation work had been done by Massachusetts and other states; so that the general public was already educated to the importance of the fact that water could be purified for drinking purposes and that sewage could be rendered less harmful before entering the streams and was aware of how these results could be accomplished. Therefore, the people of Pennsylvania were prepared for legislation along these lines.

Legislation, however, is of little effect unless backed by a strong general sentiment; laws which are far in advance of public opinion cannot be enforced. It would do no good at the present time to pass drastic laws preventing acid entering streams. Granting the possibility, such acts would materially increase the cost of production of important items of manufacture and household use and would add to the cost of living. The problem of improving the present conditions is a serious one and thoughtful study will be required to find the best remedy and whether the mines and mills can mitigate the situation without an enormous expense.

What better agency is there than the State Department of Health to collect all of the information, to conduct experiments, to educate the public, to tell what can be done and what it will cost? Then, provided a reasonable solution of the problem is found, we will be ready for thorough and effective legislation. It is idle to suppose that any one concern or corporation can alone stand the expense of such an investigation, nor can they be effectively punished for continuing along present lines until some adequate remedy for the situation be found.

The State and the Governor have certainly been paternal with regard to the agencies of relief in such instances as recently occurred at Austin. The latter has expressed his interest in the paper before us for discussion this evening. I take it our Society could perform no better public service than to endeavor, through influence and petition to secure such broad investi-

gation and thorough study of this problem that its solution might be obtained and the people of this state educated to demand the legislation which would result in the needed improvement.

Mr. J. C. Wm. Greth:* That the Monongahela River is a badly contaminated supply has been pointed out in considerable detail and it has been plainly shown that free acid and acid salts in drainage from coal mines is the principal cause of the contamination. The discharge of acids from the manufacturing plants contributes but a small percentage of the total contamination.

In speaking of mine drainage it should be borne in mind that many mine waters are not acid but decidely alkaline and that such waters tend to mitigate the evils arising from the discharge of acid waters, both on account of the dilution and the reactions between the various substances in solution, neutralizing the free sulphuric acid and acid salts of the river water.

The following analysis shows a mine water of high alkalinity:

Volatile & Org. matter	5.60	Volatile & Org. matter	5.60
Silica	1.10	Silica	1.10
Iron & Alumina oxides	.15	Iron & Alumina oxides	.15
Calcium oxide	2.80	Calcium carbonate	5.00
Magnesium oxide	1.84	Magnesium carbonate	3.86
Sodium oxide	103.35	Sodium carbonate	62.18
Sulphuric anhydride	52.00	Sodium sulphate	92.50
Carb. Anhydride (Fxd)	30 03	Sodium chloride	50.35
Carb. Anhydride (Free)	none	TOTAL SOLIDS	220.54
Chlorine	30.55	Suspended Matter	.45
Alkalinity as $CaCO_3$	68.25	Free Carbonic acid	none

Non-incrusting Solids	204.83
Incrusting Solids	10.11

Mr. Campbell cited as an exceptional case one mine water from an abandoned mine in which the free acid content was 1000 grains per U. S. gallon (less than two percent solution). The average of the total acids and acid salts in mine drainage,

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will not exceed 100 grains per U. S. Gallon (less than a 2/10 of one percent solution.)

To neutralize the acids of mine drainage by the use of chemicals, of which lime stone is the cheapest, assuming drainage of average acidity, would add from 3 to 10 cents per ton to the cost of mining coal, which the coal operator would consider prohibitive. Lime can also be used, but would still further increase the cost of neutralizing the acids, etc.

When either of these substances are used, it must be borne in mind that the water will be hardened to the extent of the lime introduced, for the lime combining with the sulphuric acid would be present in the water in the form of calcium sulphate, assuming that the lime stone or lime used is a calcium lime. Further, if such a treatment be made upon the mine waters of high acidity, calcium sulphate may be present in excess of its solubility, therefore some of it may be in suspension, and if means were not provided to filter out the excess, it would either be deposited on the beds of the streams, or be re-dissolved and harden the entire water supply. If a magnesium lime were used the resultant magnesium sulphate would be dissolved, it being so soluble as to enable the water to carry in solution any amount that may be introduced in neutralizing acid mine drainage.

The various manufacturing plants having an acid waste, similar to acid mine drainage, but containing very much larger quantities are able to obtain at a profit a by-product, iron sulphate or copperas, but with the mine drainage the cost of concentrating and the removal of impurities to obtain this same by-product would be out of all proportion to its present market value.

The seepage from abandoned mines presents another phase to the problem of preventing stream pollution. Water from these old mines contains much more free acid and acid salts than at the time the mine was being worked. To place the responsibility for contamination from this source opens up a rather difficult question to be decided. It may not be out of place here to refer to the pollution of underground and surface water sup-

TABLE NO. 1. ANALYSIS OF MONONGAHELA RIVER WATER FROM WORTHINGTON, W. VA., TO PITTSBURGH, PA., DURING 1905-1911.

LOCATION	DATE	Vol. & Organic Matter	Silica	Iron & Alumina Oxides	Calc. Carb.	Calc. Sulph.	Calc. Chlor.	Magn. Carb.	Magn. Sulph.	Magn. Chlor.	Magn. Nitr'e	Sod. Sulph.	Sod. Chlor.	Sod. Nitr'e	Suspen Matter	Iron Sulph.	Alum. Sulph.	Free Sulph. Acid	Alka-linity	Total Solids
Worthington, W. Va.	9-6-10	0.90	1.55	0.25	0.50	5.17			0.96			1.06	2.31	0.08	7.80				0.50	12.78
Fairmont, W. Va.	7-28-09	0.35	0.65	0.35		9.96			3.45			5.66	1.15		0.25				Neutral	21.57
Fairmont, W. Va.	7-25-10	1.05	0.65	0.05	0.25	1.56			0.48				0.49	0.14	1.05				0.25	4.67
Gray's Landing, Pa.	4-15-11	0.35	0.45	0.05		2.04			0.66	0.05	0.07		0.41		1.75			0.10		4.08
Gray's Landing, Pa.	11-14-10	3.45	0.75	0.45	0.25	3.91			0.78	0.57			0.44		0.45				0.25	10.60
California, Pa.	4-8-11	0.55	0.45	0.15	1.00	0.68			1.41			0.96	0.49	0.16	0.35				1.00	5.85
Charleroi, Pa.	9-8-06	1.20	0.85	0.25		3.64		0.44	0.27	0.43	0.14		0.13		0.90				0.50	7.35
Monessen, Pa.	7-12-05	0.50	0.55	0.25	0.09	2.30		0.69					0.50		2.75				1.25	4.88
Monessen, Pa.	5-24-09	0.40	0.45	0.10		3.40			1.08			0.34	0.82	0.08	0.65			0.25		6.67
Monongahela City, Pa.	7-13-08	0.25	0.65	0.25	0.50	4.18			0.99			0.99	0.82		0.70				0.50	8.63
Monongahela City, Pa.	10-12-08	1.90	0.85	0.25		6.56			2.40			2.70	1.32	0.16	0.80			0.86		16.14
McKeesport, Pa.	9-19-07	0.55	0.75	0.45	0.11	3.74		0.97			0.04		0.82	0.11	3.55				1.25	7.54
McKeesport, Pa.	11-13-08	4.20	0.25			15.54			3.78			8.66	1.82	0.16	1.65	5.05	1.14	1.72		40.60
Demmler, Pa.	9-14-06	0.25	0.55	0.80		6.07			2.88	0.20			0.58		1.75			2.22		11.33
Duquesne, Pa.	2-4-05	0.55	0.28			3.28			1.17			0.87	0.66	0.31	0.60	0.95		0.12		8.07
Braddock, Pa.	2-4-07	0.65	0.75			5.10			2.22		0.18		0.46	0.11	1.95	1.01	0.57	1.88		11.05
Rankin, Pa.	12-12-08	0.45	0.65			17.97			7.14			6.44	2.64	0.16	0.55	4.09		1.71		39.54
Rankin, Pa.	2-23-10	0.75	0.45	0.20		3.40			0.30	0.07	0.14		0.58		8.95				Neutral	5.89
Glenwood, Pa.	12-11-08	0.20	0.45	0.15		17.97			6.90			7.33	2.64		0.45	3.61		0.24		39.25
Pittsburgh, Foot Wood St.	4-19-09	0.80	0.45	0.10		2.72			0.84			0.14	0.58	0.16	2.55				Neutral	5.79
Pittsburgh, Foot Wood St	4-5-07	0.75	0.45	0.15		5.83			2.70			2.40	0.66		0.80			0.74		12.94
Pittsburgh, Foot Wood St.	12-1-08	0.90	0.55	0.75	0.75	18.41			5.82			6.83	3.79		0.75				0.75	37.80

REMARKS:—Analysis made of the filtered sample. Total solids does not include suspended matter.

plies from water discharged from present and abandoned oil wells, which still remains an unsettled problem.

If a feasible method was devised for preventing the contamination of our rivers which could be operated at a profit or even pay for the cost of purification, there would be no trouble experienced in putting it into use, but on the other hand, if this contamination was prevented at a loss to the individual mine owner, which now appears to be the case, it would be a discrimination to enforce such purification, for mines from which only alkaline water is discharged would not have the extra expense; while those with acid drainage would be handicapped by the additional expense.

To illustrate the variations in the quality of the Monongahela River I have selected from a large number of analyses the following, shown in Table 1, from points beginning with Worthington, W. Va. on the West Fork of the river and terminating at the foot of Wood Street in Pittsburgh.

At some of the more important points are shown the worst and best analysis. The analyses for a given point, are as a rule taken from the same intake, so that they actually represent different conditions at different times.

From these analyses it would seem that even at the present time, that at almost any point on the river between the points I have mentioned, the water varies from acid to alkaline, and the total soluble impurities will vary from four grains to 40 grains per U. S. Gallon.

The following curves, Fig. 9, were plotted from analyses of Monongahela River water made during 1905 and 1904, showing the amount of lime and soda ash required for the complete softening and purification of the water. These analyses are arranged by the months in which the samples were taken. These samples were all taken from the north side of the river between McKeesport and Pittsburgh, and as a rule, from the intake along the bank.

The comparative quantities of reagents required for different stages and seasons can readily be obtained from the curve. These curves will show a variation in the soda ash required from 2/10 lb. per 1000 gallons to nearly two lb., and the lime from

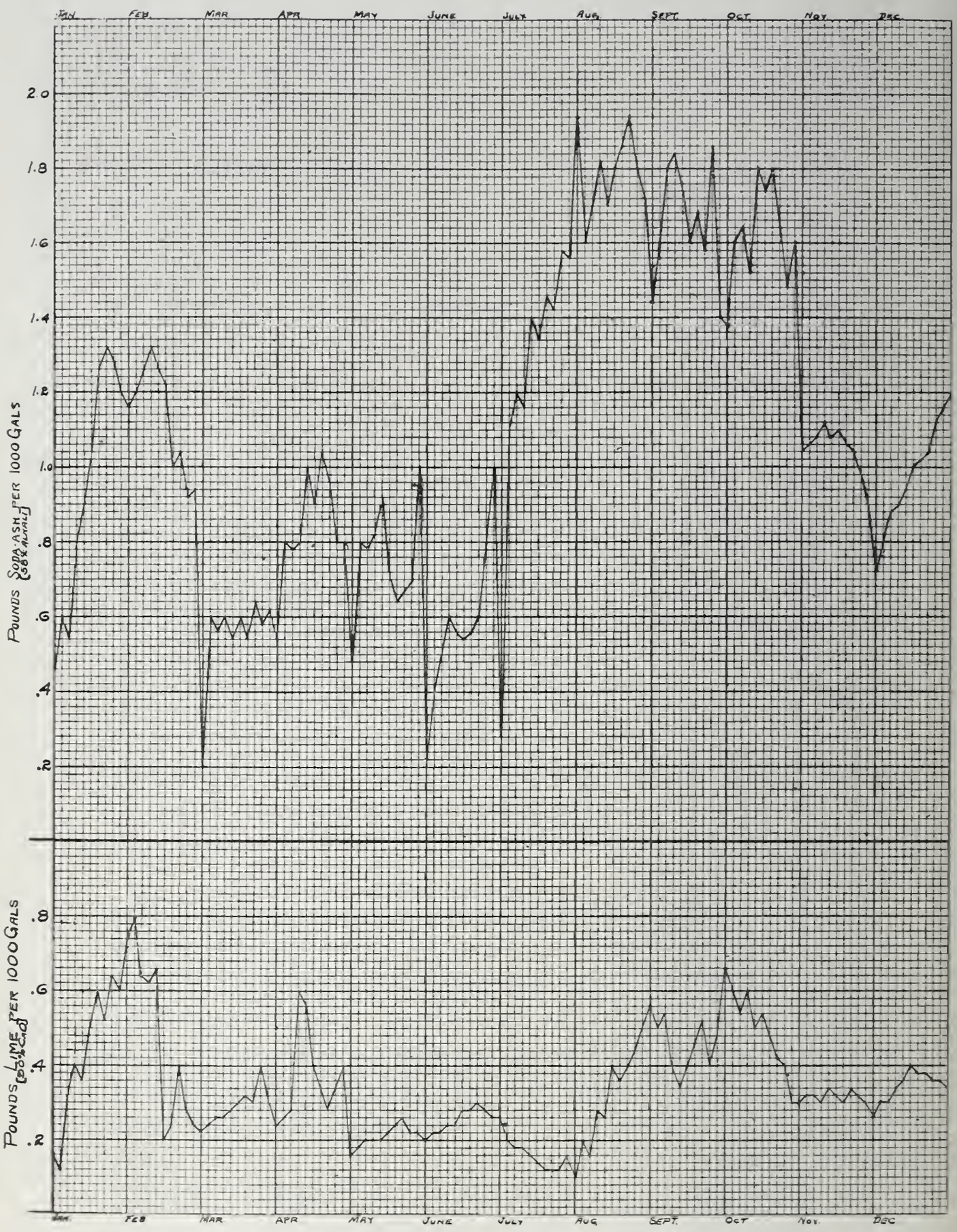

Fig. 9. Treatment of Monongahela River Water. Samples taken from north side of river between

less than 2/10 lb. to 8-10 lb. per 1000 gallons, or a variation in cost of treatment of from less than ½¢ per 1000 gallons to over 3¢ per 1000 gallons; based on lime at ½¢ per lb. and soda ash at 1¼¢ per lb.

These costs of treatment are not at all exceptional. There are hundreds of water supplies in the United States, which might be called about average supplies, where the cost of softening is considerable in excess of 3¢ per 1000 gallons. I believe that 1¢ per 1000 gallons represents a fair average cost for complete softening, neutralization and purification, of the Monongahela River in its present condition.

The extreme variations in the river supply cannot be charged entirely to the introduction of manufacturing waste or mine drainage, but to the wide variations in the volume of water discharging from the tributaries corresponding to the irregular rain fall.

Mr. C. A. Finley*: Col. Roberts' paper is of considerable interest to the City of Pittsburgh, in that it predicts the possible future condition of the Allegheny River which is the source of supply of Pittsburgh's drinking water.

The intake for the Pittsburgh Filtration Works is a short distance above the borough of Aspinwall, on the west bank of the Allegheny River. The Allegheny River is considered comparatively free from mine and mill waste. For several reasons, the Freeport vein which lies largely on the Allegheny water-shed has not been worked as extensively as has the Pittsburgh vein which lies largely on the Monongahela water-shed. It seems reasonable to believe, however, that the Freeport vein will ultimately be worked to its capacity. It is entirely possible, therefore, that the waters of the Allegheny will then experience the same general chemical changes as have been experienced in the Monongahela.

Already some of the tributaries of the Allegheny have been materially affected by mine waste, mill waste, or a combination of the two. Most notable of these are the Kiskiminetas, the Conemaugh, the Loyalhanna and Black Lick. These streams are

*Superintendent, Bureau of Water, Pittsburgh.

known to receive the mine drainage from operations of considerable magnitude. Many Pittsburghers remember the Kiskiminetas Creek as very attractive fishing grounds. For several years past, however, the stream has been entirely devoid of fish, on account of the acid condition of the water.

The appearance of the water at the junction of the Allegheny and the Kiskiminetas at Kiskiminetas Junction is generally very striking. There is a very distinct line of demarcation between the brown, alkaline water of the Allegheny and the blue or green acid water of the Kiskiminetas. In general, the main body of the river below the junction remains brown, because of the preponderance of Allegheny river water. It is true however, that a ribbon of blue water generally persists along the east bank of the Allegheny River to a point below Brilliant Pumping Station. This ribbon varies in width from a very narrow strip to half the width of the river. Occasionally the entire width of the river is blue, and it should be particularly noted that these latter occasions are rapidly increasing in frequency.

Available records show no actual acid condition of the Allegheny at Aspinwall prior to the time of installation of the filtration works, althought it is well remembered that there was a visitation of dead fish at least as early as 1904. The old records of the Pittsburgh Filtration Commission in 1898 show no acid conditions. It is therefore fair to assume that alkaline water constantly prevailed. The report of that Commission, however, refers to the possibility of future acid water and the effect of such water upon the economy and efficiency of various methods of filtration.

Authentic records of the alkalinity of the Allegheny River from 1899 to 1908 are not readily available. Starting September 15th, 1908, daily records of the alkalinity of the Allegheny River water at Aspinwall have been kept. An accompanying chart shows the results, together with the river elevations, from January 1st, 1909 to October 31st, 1911.

During March, April and May 1909, a comparative study of the alkalinity of the two sides of the river at Aspinwall was made, with results as shown by the following table:

TABULATION OF ALKALINITY OF ALLEGHENY RIVER WATER AT ROSS PUMPING STATTION IN COMPARISON WITH ACIDITY OR ALKALINITY BELOW BRILLIANT PUMPING STATION.

	MARCH		APRIL		MAY	
Date 1909	Ross Pumping Station Alkalinity. P.P.M.†	Brilliant Acidity. P.P.M.	Ross Pumping Station Alkalinity. P.P.M.	Brilliant Acidity. P.P.M.	Ross Pumping Station Alkalinity. P.P.M.	Brilliant Acidity. P.P.M.
1	11.0		15.0		11.0	2.0
2	16.0		15.0			
3	13.0		15.0	3.0	10.0	
4	12.0				10.0	1.0
5	11.0		19.0		11.0	
6	12.0		18.0	1.0*	12.0	1.0
7			21.0		13.0	
8	18.0		13.0		13.0	3.0
9	18.0		18.0			
10	14.0		18.0	Neutral	17.0	
11	13.0				16.0	Neutral
12	15.0		19.0		15.0	
13	13.0		19.0	0.5*	20.0	1.5
14			19.0			
15	15.0		19.0			
16	17.0		16.0			
17	20.0		16.0	3.0		
18	18.0					
19	19.0		15.0			
20	18.0	2.0	16.0	1.0		
21			17.0			
22	22.0		18.0			
23	20.0	2.0	14.0			
24	20.0		16.0	Sample lost		
25	16.0	3.0*				
26	14.0		23.0			
27	18.0	2.0	17.0	4.0		
28			16.0			
29	15.0		15.0			
30	15.0		15.0			
31	15.0	2.5				

*In the results from Brilliant the figures starred are alkalinity.

†The results are given in parts per million by weight.

In determining the degree of alkalinity, lacmoid was used as an indicator. In determining the degree of acidity, phenolphthalein was used. Sulphates and chlorides of iron and aluminum are neutral to lacmoid, and acid to phenolphthalein.

These interesting results led us to investigate the source of the acid condition and the clarifying action on the Brilliant side of the river.

On June 10th, 1909, samples were collected at Natrona, Butler Junction and Kiskiminetas Junction with the following results:

TABULATION OF IRON AND ALKALINITY RESULTS FROM SAMPLES COLLECTED ON THE ALLEGHENY RIVER, JUNE 10TH-11TH, 1909.

Date	Sample	Alk. P.P.M.	Total Iron P.P.M.	Dis. Iron P.P.M.	Susp. Iron P.P.M.
June 10	Allegheny River above Penna. Salt Works, Natrona..	12	3.4	0.1	3.3
June 10	Outlet Sewer from Penna. Salt Works, Natrona	18	3.4	0.0	3.4
June 10	Allegheny River below Penna. Salt Works, Natrona..	20	...	0.0	...
June 11	Allegheny River at Butler Junction, near highway bridge, North Side	20	3.2	0.6	2.6
June 11	Allegheny River at Butler Junction, South Side.	—4	105.0	0.0	105.0
June 11	East Side of Kiskiminetas Creek at A. V. R. R. bridge.....	—2	75.0	0.0	75.0
June 11	Allegheny River, south side above Kiskiminetas Creek	15	8.8	1.9	6.9

By qualitative test, no iron in the ferrous state was detected in any of the above samples.

Having determined that the acid tendency did not obtain in the Allegheny River above Kiskiminetas Junction, it was determined to make a further investigation of the Kiskiminetas.

On August 19th, 1909, there were many dead fish in the river. Believing this to be caused by acid action, an investi-

gation was started. It was found that the Allegheny was alkaline up to the Kiskiminetas, but that the Kiskiminetas was actually acid. The following tabulation will give concisely the results obtained:

Location	Acidity P. P. M.
Stony Creek above mouth of Little Conemaugh	4.0
Clapboard Creek near Little Conemaugh	159.0
Saxman's Run between Loyalhanna and Latrobe	85.7
Loyalhanna Creek below Saxman's Run	257.0
Loyalhanna Creek above Saxman's Run	48.0
Small Run above Windber	133.0
Mine waste from Mine No. 36	75.0
Mine waste from Mine No. 35	86.0
Paint Creek at Paint Creek Station	172.0
Stony Creek above mouth of Paint Creek	3.0
Stony Creek 250 ft. below Paint Creek	111.0
McGee's Run near mouth at Cokeville	36.0

Careful examination led to the belief that coal mine wastes were the real source of the acid conditions. In order to determine definitely the condition of steel mill wastes, however, a study of the effluents from the Cambria Steel Company at Johnstown was made. The following results were obtained:

Location	P. P. M. Alkalinity	P. P. M. Acidity
Stony Creek above mouth of Little Conemaugh		4.0
Little Conemaugh, above dam, Gautier Department	6.0	
Little Conemaugh, below dam, Gautier Department	8.0	
Clapboard Creek near Little Conemaugh		159.0
Little Conemaugh above Clapboard Creek	4.0	
Little Conemaugh above culvert Cambria Steel Company	22.0	
Little Conemaugh at culvert Cambria Steel Company	7.0	
Sewer, 12 in., near Steel Car Department, Cambria Steel Company		28.0
Little Coneamugh below culvert and above 12 in. sewer	27.0	
Conemaugh River below blast furnace	8.0	
Conemaugh River 150 ft. below dam at blast furnace	6.0	
Sewer, 24 in., lower end Cambria Steel Company's furnace	14.0	

Small Creek under Railroad bridge below blast furnace	46.0	
Small culvert, centre of mill, below junction of Little Conemaugh and Stony Creek	45.0	
Stony Creek near Moxham, above Lorain Steel Company		42.0

Having gotten these data concerning wastes from mines and from steel industries, it was determined to study more fully the conditions near the mouth of the Kiskiminetas. The following results were obtained on August 21st, 1909:

Location	P. P. M. Alkalinity	P. P. M. Acidity
Allegheny River, south side, above Kiskiminetas Creek	53.0	
Kiskiminetas Creek at Kiskiminetas Junction, east side		66.0
Kiskiminetas Creek at Kiskiminetas Junction, west side		67.0
Allegheny River, north side, opposite Kiskiminetas Creek	53.0	
Small Mine Run near Leechburg		10.0
West shore Kiskiminetas Creek above Leechburg .		52.0
Kiskiminetas Creek opposite West Appollo Station		39.0
Beaver Run at West Appollo	43.0	
Kiskiminetas Creek above Beaver Run		45.0

It would seem that the results obtained show conclusively that the Kiskiminetas has much to do with the occasional acid tendencies of the Allegheny.

Available records seem to show that the entire cross section of the Allegheny River at Aspinwall first became actually acid on October 17th, 1909. The following table shows the results obtained at that time:

Time October 17th, 1909.	P. P. M. Alkalinity	P. P. M. Acidity
2 A. M.	24.0	
10 A. M.	9.0	
6 P. M.		5.0
10 P. M.	slightly	

The accompanying figures will show the clarifying effect of the acid action upon the river water.

SILICA TURBIDITIES, PARTS PER MILLION, OF ALLEGHENY RIVER AT ASPINWALL.

Time	Turbidity	Time	Turbidity	Time	Turbidity
Oct. 16th, 1909.		Oct. 17th. 2 A. M.	25	Oct. 18th. 2 A. M.	9
10 A. M.	43	4 A.M.	20	4 A. M.	9
noon	47	6 A. M.	20	6 A. M.	..
2 P. M.	50	8 A. M.	20	8 A. M.	..
4 P. M.	50	10 A. M.	20	10 A. M.	13
6 P. M.	..	noon	20	noon	13
8 P. M.	40	2 P..M	13	2 P. M.	11
10 P. M.	35	4 P. M.	13		
midnight	30	6 P. M.	11		
		8 P. M.	11		
		midnight	9		

In connection with these results, it might be said that a silica turbidity of six parts per million is just noticeable in a drinking glass, under ordinary conditions.

The clarification was evidently very pronounced.

The bacterial content of the river water also was markedly affected as shown by the following table:

Time 1909	Bacteria Per C. C.	B. Coli Per C. C.
Oct. 14th	14 000	25
" 15th	26 000	50
" 16th	96 000	10
" 17th	.....	..
" 18th	3 600	0
" 19th	50 000	10
" 20th	180 000	100
" 21st	80 000	25

No marked approach to acid condition was again noted until September 7th, 1910, when it reached an alkalinity of three parts per million. Again on September 17th, 1910, it fell to an alkalinity of one part per million. No actual acid water was found, however, during the year 1910.

On June 8th, 1911, the river at Aspinwall again became acid. The following results show the change:

Time	P. P. M. Alkalinity	P. P. M. Acidity	Time	P. P. M. Alkalinity	P. P. M. Acidity
1911			noon		3.0
June 7th			2 P. M.		3.0
8 A. M.	21.0		4 P. M.		2.0
June 8th			6 P. M.		3.0
8 A. M.	8.0		8 P. M.		1.0
2 P. M.		1.0	10 P. M.		2.0
4 P. M.	0	0	midnight		slightly
6 P. M.	0	0	June 10th		
8 P. M.		1.0	2 A. M.		slightly
10 P. M.		3.0	4 A. M.	4.0	
midnight		3.0	8 A. M.	8.0	
June 9th			June 11th		
2 A. M.		4.0	8 A. M.	14.0	
4 A. M.		4.0	June 12th		
6 A. M.		3.5	8 A. M.	16.0	
8 A. M.		3.5	June 13th		
10 A. M.		3.0	8 A. M.	22.0	

The following table shows the change in turbidity of the river water during this period:

SILICA TURBIDITY P. P. M. OF ALLEGHENY RIVER AT ASPINWALL, JUNE 7-13, 1911.

	June 7	June 8	June 9	June 10	June 11	June 12	June 13
2 A. M.	40	110	8	9	14	13	11
4 A. M.	45	55	6	9	11	12	12
6 A. M.	50	60	7	9	10	15	13
8 A. M.	40	40	8	12	11	14	12
10 A. M.	45	13	8	16	10	11	15
noon	40	12	9	13	12	10	16
2 P. M.	60	12	7	15	14	11	18
4 P. M.	60	13	7	15	13	13	16
6 P. M.	85	11	8	18	12	..	22
8 P. M.	150	10	8	12	10	12	20
10 P. M.	110	10	7	10	11	13	24
midnight	100	9	8	13	12	12	25

The effect of the acid water upon the bacterial content of the river water is shown by the following figures:

Date 1911	Bacteria Per C. C.	B. Coli Per C. C.
June 6th	20 000	100
June 7th	80 000	25
June 8th	58 000	10
June 9th	9 400	0.1
June 10th	27 500	10
June 11th	50 000	50
June 12th	54 000	10
June 13th	39 000	100

On June 29th, 1911, the river at Aspinwall again became acid. The following table shows the results obtained:

Date 1911	Time	Turbidity P. P. M.	Alkalinity P. P. M.	Acidity P. P. M.
June 28	noon	33	....	....
"	2 P. M.	27	....	....
"	4 P. M.	25	16.0	....
"	6 P. M.	28	12.0	....
"	8 P. M.	..	11.0	....
"	10 P. M.	10	6.0	....
"	midnight	7	2.0	....
June 29	2 A. M.	7	0	0
"	4 A. M.	9	....	3.0
"	6 A. M.	8	....	4.0
"	8 A. M.	7	....	4.0
"	10 A. M.	5	....	3.0
"	noon	6	....	1.0
"	2 P. M.	8	2.0	....
"	4 P. M.	10	6.0	....
"	8 P. M.	16	9.0	....

On July 19th, 1911, the river at Aspinwall again became acid. The following table shows the results obtained:

Date 1911	Time	Turbidity P. P. M.	Alkalinity P. P. M.	Acidity P. P. M.
July 19	12:01 A. M.	18	13.0	....
"	2 A. M.	15	13.0	....
"	4 A. M.	18	12.0	....
"	6 A. M.	15	9.0	....
"	8 A. M.	15	9.0	....
"	10 A. M.	9	5.0	....
"	noon	10	5.0	....
"	2 P. M.	10	5.0	....
"	4 P. M.	10	4.0	....

Date 1911	Time	Turbidity P. P. M.	Alkalinity P. P. M.	Acidity P. P. M
July 19	6 P. M.	9	3.0	....
"	8 P. M.	8	2.0	....
"	10 P. M.	7	....	1.5
"	midnight	8	....	2.5
July 20	2 A. M.	4	....	3.0
"	4 A. M.	5	....	5.0
"	6 A. M.	5	....	5.0
"	8 A. M.	5	....	6.0
"	10 A. M.	7	....	7.0
"	noon	6	....	7.5
"	2 P. M.	7	....	7.0
"	4 P. M.	6	....	8.0
"	6 P. M.	5	....	7.5
"	8 P. M.	5	....	7.0
"	10 P. M.	5	....	6.0
"	midnight	5	....	6.5
July 21	2 A. M.	4	....	6.5
"	4 A. M.	4	....	6.0
"	6 A. M.	4	....	6.0
"	8 A. M.	5	....	4.5
"	10 A. M.	5	....	3.5
"	noon	4	....	2.0
"	2 P. M.	4	....	1.0
"	4 P. M.	5	....	0.0
"	6 P. M.	4	1.5	....
"	8 P. M.	4	4.0	....
"	10 P. M.	5	4.0	....
"	midnight	5	6.0	....
July 22	2 A. M.	6	6.0	....
"	4 A. M.	7	9.0	....
"	6 A. M.	6	9.5	....
"	8 A. M.	6	9.5	....
"	10 A. M.	7	9.5	....
"	noon	6	10.0	....

The effect upon the bacterial content of the river water during this period is shown in the following table:

Date 1911	Bacteria Per C. C.	B. Coli Per C. C.
July 18th	1 600	50.0
July 19th	1 200	1.0
July 20th	80	0.1
July 21st	210	0.0
July 22nd	1 700	1.0
July 23rd	4 300	50.0

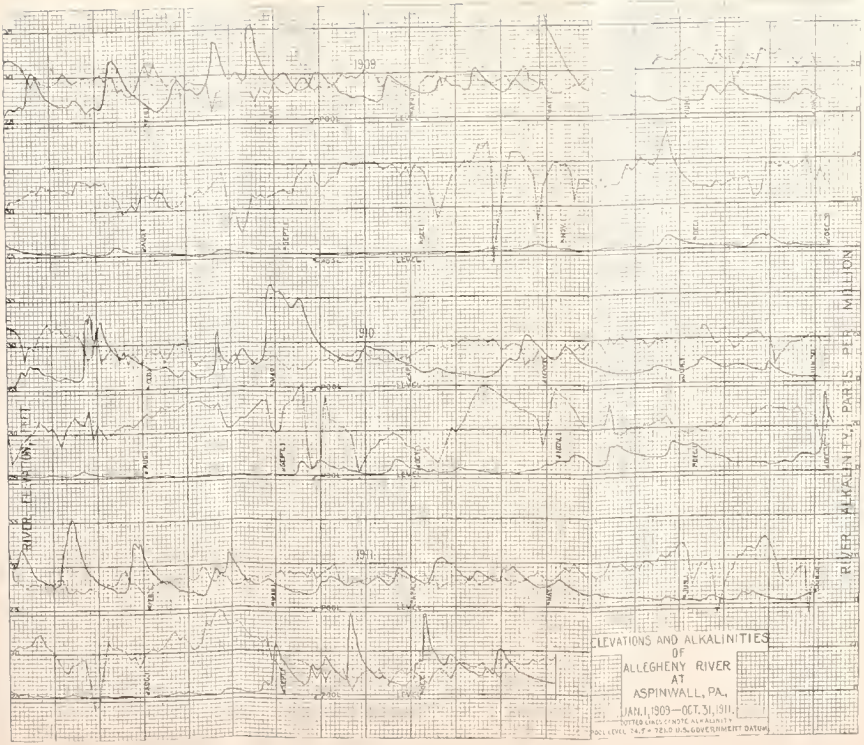

Fig. 10. Elevations and Alkalinities of Allegheny River at Aspinwall, Pa., Jan. 1st, 1909 to Oct. 31st, 1911.

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During this latter period a great many dead fish floated down the river. This condition has always taken place with an acid river water, but it was particularly pronounced on July 20th. An effort was made to determine the actual cause of the killing of the fish.

The author of the paper of the evening advances the theory that the death of the fish is due to the absence of free oxygen on account of the presence of acid. The results obtained at Aspinwall seem to be at variance with this theory:

Date 1911	Dissolved Oxygen P. P. M.	Carbonic Acid P. P. M.
July 17th	7.6	5.3
July 18th	6.3	5.3
July 19th	8.1	8.8
July 20th	7.9	17.6
July 21st	7.6	16.3
July 22nd	8.4	5.7
July 23rd	...	....
July 24th	8.1	4.0
July 25th	7.9	....

It is evident that there was a sufficient supply of uncombined oxygen at all times to preserve life. Attention is called to the extremely high carbonic acid in the river water on July 20th and 21st. May the death of the fish not have been due to the presence of an excessive amount of carbonic acid rather than to a deficiency of oxygen?

There have therefore been three well defined periods of acid river water at Aspinwall during the summer of 1911. Reference to the alkalinity chart, Fig. 10, shows that the alkalinity has been under twenty parts per million during nearly all of the past year. It would seem that the probability of long periods of acid river water at Aspinwall in the near future is therefore great.

The author refers to "mottled" water on the Monongahela River. This peculiarity has been very common on the Allegheny. It generally appears during the transition from high to low alkalinity. At these times, there is generally a clarification throughout the body of the river. Scattered through the clarified water are irregular dark brown patches varying

in size from two to twenty feet in length. They are well defined, appearing like patches of mud in an otherwise clear water. Unfortunately these patches are not visible at short range. It has therefore been impossible to get isolated samples for investigation. They have been considered, at the Filtration Works, as masses of alkaline water which have not closely intermingled with the acid waters up-stream, and have therefore not been subjected to the clarifying action. In this connection it should be borne in mind that not all the blue water is acid. Much of it is simply clarified alkaline water,—clarified but not acidified by contact with the acid waters up stream.

In spite of these acid periods, there has never been a time when the filtered water at Aspinwall has been even dangerously near acid condition. The alkaline material in the filters has always been sufficient to overbalance the acidity of the applied water.

Since the acid water reduces the turbidity and the bacterial content of the river water, the question may be asked, "Why is this condition not beneficial to filtration?" There are several reasons why it is distinctly detrimental:

First: Acid water attacks the top coating of the sand surface, rendering it porous and unfit to perform its function. A series of measurements has shown that soon after the first application of acid water, the resistance to flow through the filtering media actually decreases. In technical terms, the loss of head decreases rather than increases. Later, when the alkaline water returns, the loss of head increases very rapidly, crippling all filters then in operation. Examination shows that a cementing action has taken place in the upper portion of the sand. This cementing material is believed to be an iron compound,—perhaps carbonate of iron.

Second: There can be no certainty how long the acid period may remain. Extreme care must therefore be taken to have the filters in condition to purify the water which follows the acid water.

Third: High iron content has usually been found in the filtered water at times when the applied water has tended toward acid condition. This iron has given the filtered water a

yellowish brown coloration which, though slight, is objectionable to the consumer.

Fourth: No water purification system can be operated on the most economical basis, with a raw water of rapidly and widely varying changes of chemical composition. The time may come when some form of alkaline material must be introduced into the river water as a corrective of the acid.

The control of acid wastes in the Allegheny River is therefore of considerable importance in Pittsburgh's water supply, from an economical and a sanitary standpoint.

Mr. Farley Gannett‡: Mr. President, and gentlemen; When I reached Pittsburgh to-night your Secretary informed me that owing to the inability of a representative of the Attorney General to come to Pittsburgh, he desired me to tell your Society what I could of the laws controlling the discharge of effluents from mines and manufacturing plants into the rivers of Pennsylvania.

There seem to have been a number of laws enacted by the Legislature which apply to this question to a certain degree, but as I am not a lawyer, I cannot attempt to cover the ground with authority or thoroughness.

In the first place it would seem that the Federal Statute which Col. Roberts quotes in his most valuable paper should be interpreted to apply to the deposition of acid wastes from mine openings and pickling tanks.

The Pennsylvania Fisheries Acts, and supplements thereto, provides that substances injurious to the fish must be kept out of the streams. The Supreme Court, however, has interpreted this act to permit of some such pollutions, where the greater public good would be served thereby, thus essentially modifying the act and limiting considerably its applicability. This Department has been active in stopping and preventing minor and unnecessary pollutions of this character.

The Health Department Act of 1905, prohibits the interference by that Department in the discharge of mine and tanning wastes into the streams, so that that Department, so active and so beneficial along other lines of stream pollution, cannot

‡Chief Engineer, Water Supply Commission of Pennsylvania, Harrisburg.

prevent the introduction of acid mine impurities into the waterways.

The Water Supply Commission Act of May 28, 1907, known as the "Stream Encroachment Act," prohibits the alteration of the cross-section, current or carrying capacity of public highway streams in any manner whatsoever, except by express authority and approval of that Commission. Therefore the discharge of any material which causes the deposition of precipitates in the rivers should come within the jurisdiction of this Act. The Act was prepared primarily to control the introduction of solid matter into the rivers, and the encroachment by fills and waste piles, upon their channels, and much benefit has been derived thereby. The Commission has confined its labors largely to this class of work, together with passing on all bridge piers, dams, etc. which would obstruct the flow.

In the anthracite coal district the most injurious waste is the culm and sand which comes into the streams as discharge from the washeries, or is washed from the waste piles near the mines. This material is deposited on valuable agricultural lands during floods, destroying much property, and makes purification for domestic and manufacturing purposes costly.

The valleys of the streams receiving this material from the anthracite field are not provided with manufacturing plants of such great proportions, or in such large numbers, as are your western streams, so that the question of acidity of the water has not reached such far reaching importance on these streams. Furthermore there is much more limestone water entering the eastern streams from tributaries draining vast limestone areas than enters the Allegheny or Monongahela Rivers, and this water assists in neutralizing the acidity during low stages, when the limestone streams discharge proportionately larger quantities of water than other streams, while the natural dilution reduces the acidity during higher stages.

It is, I am sure, the hope of the Commission that a means may be obtained, through a careful study of conditions, by which the acid may be recovered, at a reasonable cost, so that it would be an economical proposition to keep it from the streams. Coal mining and steel manufacturing should not be stopped, or even

curbed materially, in order to reduce the acidity of the water, as these industries are at the foundation of Pennsylvania's prosperity, but if a way can be found by which industry will not be hindered, and the acids recovered, such a discovery would work to vast benefit to all the users of the waters of the Commonwealth.

Mr. James O. Handy:* I had expected to cover some of the same ground which Mr. Campbell has covered much better than I could have done. I wished to speak of the origin of the acids which occur in the rivers, coming as they do both from coal mines and from steel mills. The evolution of the acid in coal mine water can be shown by means of a chemical equation or a statement. It originates as iron pyrites or sulphide of iron which in contact with oxygen or air and moisture, produces what we know as "acid" or "sulphur." It is really a mixture of free sulphuric acid, sulphate of iron and other sulphates, as Mr. Campbell has said. After the acid water leaves the coal mines it meets alkaline water coming from the upper river, and the reaction between the lime in the alkaline water and the acids in the mine water causes the precipitation of the iron and the neutralization of the acid to a large extent.

It is remarkable what damage very small amounts of acid will cause in steam boilers. One of my first pieces of work when I came to Pittsburgh was the investigation of the amount of free acid in the Monongahela River water near the Carrie Furnaces. Some of the samples were not acid at all and others only contained very small amounts of acid. It seems to be a fact that sulphuric acid and sulphate of iron when put into steam boilers start a sort of perpetual motion operation. The acid attacks the iron and the iron salt which is formed is broken up; then the acid acts over again. There is a constantly increasing accumulation of Venetian red or iron oxide in the boiler and pitting or perforation of the boiler goes on apace.

I give at this point analyses of mine waters, water from coal washing plants and waste pickling acids from steel mills.

*Chief Chemist, Pittsburgh Testing Laboratory, Pittsburgh.

ANALYSES OF MINE WATERS.

Parts per 100 000.

	Mine K. H.	Mine K.S.	Mine J. 2.
		5 000 000 gal. per day.	
Total Acidity	375.8 parts	408.17 parts	77.42 parts
Ferrous Iron	1.5 "	3.00 "	.50 "
Ferric Iron	101.5 "	105.50 "	15.00 "
Alumina	41.0 "	29.00 "	15.86 "
Free Sulphuric Acid		42.57 "	

ANALYSIS OF WATER FROM COAL WASHER K. S.

Total Acidity	5.88 parts per 100 000
Ferrous Iron	3.50 " "
Ferric Iron	1.50 " "
Alumina	none
Free Sulphuric Acid	none

WASTE PICKLING ACIDS.

Parts per 100 000

	J. A. Wire Mill	A. M. Sheet Mill
Total Acidity	24500	20825
Ferrous Iron	13750	9550
Free Sulphuric Acid	437	4112

Mr. James O. Handy: In closing the discussion I would like to say a few words based on my long acquaintance with Col. Roberts and my knowledge that he is a charter member of this Society and that he has made numerous valuable contributions to the literature of the Society. His contributions have been in many cases epoch making. I have in mind particularly the paper on flood prevention† for which the Society awarded him a medal. I believe that was the basis of the work the Flood Commission has been doing and is still doing. I believe that the paper with which Col. Roberts has honored us this evening will also be epoch making. We have a grave problem and Col. Roberts has put us to work at it. You all honor him I hope as I personally do.

The Author: The admirable scheme for discussing acid conditions in our water courses, arranged by our Secretary and Vice-President Handy, elicited from our expert members and invited guests much new and important information. As Mr.

†"Floods and Means of Their Prevention in Our Western Rivers." Proceedings Engineers' Society of Western Pennsylvania, 1907, V. 23, p. 306.

Knowles and others stated the possibilities and cost of projects looking to the abatement of impurities in our streams should be made clear to the public, and this can only be done after a thorough discussion of all the data bearing upon the subject. The range that such discussions are likely to take may be very great but the Society is to be congratulated for having pointed out at least the direction in which to look for the most beneficial results.

The writer learned from the discussion that not alone free acids, but, as well also, provision must be made for the elimination of the ferrous sulphate and other salts conveyed by streams issuing from coal mines if our streams are to be restored approximately to their original normal conditions. To take care of such bulky solids in the mine waters means, of course, numerous, and in the case of our largest mines, extensive reduction plants.

One of the speakers estimated that the cost of neutralization at certain of the mines where sulphur was present in very considerable quantities, would be for reagents, labor, etc., about thirty cents a ton of the total coal mined, which is certainly a statement well calculated to attract serious attention. Other speakers while fully aware of the cost, but with a full realization of the damage to the public welfare to be averted, took the hopeful view that it seemed within the range of possibility to do the work and at the same time make by-products of sufficient value to offset the cost. Pigments are suggested as by-products, but great as the demand may be, it is easy to conceive the market for pigments might soon be overstocked. Other markets for the output of fluid coal mine wastes will of course be sought, and in this connection the writer would suggest to his friends, who have the requisite technical knowledge, the study of methods of making fertilizers from the mine waters. In former days in the old way of making coal gas, a portion of the waste products containing lime, as one component, had a salable value as a fertilizer, "not much but still something."

It is well known that there are extensive areas of porous and lean soils in the eastern states where gypsum, or sulphate of lime, would be an excellent fertilizer specially good as a top dressing for clover using 200 to 300 lb. per acre. Clover stubble

and roots, it is well to know, add more "humus" to soils than any other of our extensive field crops. This indirect method of securing nitrogen for the land is well worthy of experimental trial. It may be possible to concentrate mine waters by heat to some desired degree, and while still hot allow it to percolate through crushed limestone. If a merchantable gypsum does not result the writer would advise the ignition of the residum, until only solids would be left to go in the waste bank.

On the basis of one pound of coal evaporating eight pounds of water with fuel at 80¢ a ton, the drainage of a mine discharging a half gallon per second and producing 500 tons of coal daily, the cost should not exceed about 3½¢ per ton on the output of the mine. Far better this than to permit so much acidulated water to reach the streams. The writer, however, has faith in the idea that our chemists when they turn their attention to it will discover some new source of national wealth from mine wastes.

In the past decades agriculture in America has been for a great part conducted on very wasteful methods. There was too much area for the men to work, and after exhausting the virgin mould from the soil the farmers sons would "move west" leaving the old men at home. American inventors turned their attention too much to crop harvesting to the neglect of the soil which produced the crops. It is rapidly becoming a desperate situation east of the Mississippi, the last census showing a diminishing population in a great many counties, with even the state of Iowa on the backward trail.

The millions of tons of fluid waste from the mines, let us continue to believe will soon no longer be accounted a waste but a dividend maker for the country.

It is rather ominous to hear several of the speakers state, *first,* that abandoned coal mines are more productive of acids, etc., than are active mines, and *second* that the percentage of sulphur in the West Virginia coal was much greater than that in the lower river country. Such facts are quite sufficient to explain the marked increase in acid conditions noticed in the Monongahela River in the past two or three years. We are therefore doomed it appears to grow from bad to worse on an ever increasing ratio.

Mr. Dole stated that wheres in some other coal fields there was not a great population below them, but in Pennsylvania the drainage from every coal mine west of the Allegheny Mountains must necessarily pass through Pittsburgh and through the densely populated surrounding counties. If all the contaminated brooks and creeks were indicated on a map, the "affected area" would be shown to be very great. In some townships potable water for cattle is scarce, unless resort be had to pumping, but pumping and stall feeding will never make cheap beef.

Mr. Snyder stated that not only have the fish disappeared from many of our streams, but that the country is being forsaken by other forms of animal life. We may not fully realize the import of such a statement, but it may have a very serious meaning. There is such a thing in nature, the biologists tell us, as an equilibrium of beasts, birds, fish, insects, preying on each other in the happiest manner imaginable to the great relief of the boss animal, man; but the series be disturbed by the elimination of certain of the predatory species, other and perhaps very objectionable life forms, free to propagate, may come to afflict us.

Anent the capacity of the Ashokan conduits to which the writer refered as being perhaps insufficient to meet the demands now supplied from the Monongahela, Mr. Knowles called the attention of the Society to the fact that the great New York conduits had a daily capacity of 500 million gallons, leaving the inference that the author's statement was perhaps exaggerated. It may surprise Mr. Knowles, as well as others who have had no occasion to inquire into the matter, to learn that of 125 pumping stations on the main Monongahela and exclusive of any of its tributaries in 1908, reporting to the U. S. Engineer Office, the average daily duty was 494 000 000 gallons. The capacity of the pumps was 919 000 000 gallons daily. At this date, including the tributaries of the river the average daily quantity pumped is doubtless fully 600 000 000 gallons.

Mr. B. A. Ludgate:* The cost to coal compaines to neutralize the acid seems almost prohibitive, and as there is but a small

*Asst. Engineer, Pittsburgh & Lake Erie Railroad, Pittsburgh, Pa.

amount of the water of the river used for boiler and domestic purposes, it would be an unnecessary waste and expense to treat all the water, or rather to neutralize all the acid. The coal companies and other offenders might better pay the cost to individuals on the stream below that are required to treat the water. It seems probable that this waste acid could be utilized and turned into a productive by-product, and this might be accomplished sooner if the Government insisted on the acid being neutralized or kept out of the rivers.

Even if the free acid were neutralized, the water is still undesirable for use as a boiler water, or as domestic water, as the free acid has simply been neutralized and remains in the water as soluble sulphates. Soda ash and lime are the chemicals generally used to treat the water for boiler purposes, sulphate of soda and carbonate of lime being formed, the sulphate of soda remains in the water and causes considerable trouble from foaming; the calcium carbonate precipitates out of the water. When the rivers are low, the resulting amount of sulphate of soda, (being proportionate to the amount of concentration in the raw water), causes much trouble from foaming in locomotive boilers. This tendency to foam has to be met by reducing the concentration in the boiler by blowing off, or by the use of additional chemicals in the form of vegetable extracts, either of which adds additional expense to the cost of water treatment.

The P. & L. E. R. R. has an investment of $100 000 for water softeners on the Youghiogheny and Monongahela Rivers above McKeesport, and the yearly cost of chemicals (soda and lime alone) for the fully treated water is $5000.

In past years there has been comparatively more mining done along the Youghiogheny than along the Monongahela River, and from now on, the amount along the Monongahela River is being increased very much, and I understand from Mr. R. R. Hice, State Geologist, that the amount of iron pyrites in the coal fields of West Virginia, tributary to the Monongahela River, is nearly twice as much as in the coal fields tributary to the Youghiogheny River. Until within the last three years, the water of the Monongahela River never contained free acid, while now it is quite marked for months at a time. The amount of

free acid and sulphate in the Youghiogheny River has also increased very greatly in the last six years, the Youghiogheny always being much worse than the Monongahela River. The total quantity of acid in the river is not so important as the amount of concentration, which varies with the amount of acid put into, and the amount of water flowing in the river.

The rate of increase in mineral matter in the waters is indicated from the following tables, taken from the records of the P. & L. E. R. R., showing approximately the monthly averages for the months given in the years from 1906 to date:

YOUGHIOGHENY RIVER WATER.

Samples taken at Buena Vista 11.8 miles above McKeesport.

	1906						1907					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Hardness	7	9	21	12	15	12	8	11	15	16	6	15
Alkalinity	0	2	0	0	0	5	0	0	0	0	0	2
Free Acidity	0	0	4	1	2	0	0	0	2	2	0	0
Free CO_2 Gas	3	5	18	10	14	5	4	9	11	14	3	2
	1908						1909					
Hardness	28	26	60	100	100	67	26	26	23	32	17	19
Alkalinity	0	0	0	0	0	0	0	0	0	0	0	0
Free Acidity	1	3	12	21	20	9	4	2	0	4	0	1
Free CO_2 Gas	20	15	58	82	72	40	25	16	9	18	8	9
	1910						1911					
Hardness	22	65	71	110	82	21	15	22	7	7		
Alkalinity	0	0	0	0	0	0	0	0	0	0		
Free Acidity	3	14	14	25	18	2	3	7	0	0		
Free CO_2 Gas	19	62	62	82	64	10	14	22	3	3		

MONONGAHELA RIVER WATER.

Samples taken at Newell Station 34.5 miles above McKeesport.

	1906						1907					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Hardness										6		
Alkalinity										3		
Free Acidity										0		
Free CO_2 Gas										3		

Samples taken at Sunnyside Station 18.4 miles above McKeesport.

	1908						1909					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Hardness	8	8	10	16	22	22	9	6	7	8	7	7
Alkalinity	1	1	0	0	0	0	0	1	0	0	0	0
Free Acidity	0	0	1	1	1	1	1	0	0	0	0	0
Free CO_2 Gas	2	2	6	7	9	7	5	3	3	4	3	3

	1910						1911			
Hardness	7	11	11	24	24	9	9	16	7	6
Alkalinity	1	0	0	0	0	0	0	0	0	1
Free Acidity	0	1	2	4	3	0	0	3	0	0
Free CO_2 Gas	3	6	7	12	16	3	5	11	2	2

The amounts indicated, show parts per 100 000. The hardness shown, is that by the standard soap test. The Alkalinity and Free Acidity is that shown by titration with Methyl Orange indicator. The Free CO_2 Gas, is that shown by titration with Phenolphthalein as indicator; all tests being made cold.

In the case of free acid waters having a free acidity of over about four, from experiments made in complete analysis, the hardness is about one-half, and the free acid is about twice that shown, while two-thirds of the amount of free CO_2 gas shows about correctly for the amount of lime treatment for combined and free CO_2 gas.

Mr. G. M. Lehman:† Col. Roberts in his interesting and instructive paper comments on the suggestion of a friend that storage reservoirs be built for the dilution of the acid water of the Monongahela. The paper considers that reservoirs built for this purpose would be too costly for the resulting benefits, but nothing is said about the need of building reservoirs for other purposes, or that, in combination with the other benefits of a well-regulated reservoir system, much good could be accomplished, at the same time, toward reducing the acid trouble.

The following is quoted from the paper in question: "Some slight reservoir effect on the river would be at times desirable, but to permanently and materially increase the river current would be a detriment to navigation, and a source of considerable increase in cost of maintenance of the locks and dams, especially in the item of repairs."

†Engineer of Surveys, Flood Commission, Pittsburgh.

The writer is glad to see that Col. Roberts believes that even slight reservoir effect would be desirable and from this it would naturally be inferred that more than slight reservoir effect, at times, would be still more desirable.

Concerning the increase of velocity due to the discharge of the stored flood water, it may be stated that the delivery of this water need not be allowed to go beyond the general needs of the low-water season, for which period the water could be carefully conserved and measured out for the benefit of the various interests involved.

Mr. N. R. Buller:* The Department of Fisheries was organized for the conservation of fish life, fish being an important food supply. Artificial propagation has proven so successful as to solve the problem of maintaining the fish supply as is proven by the growth of the commercial fisheries in the port of Erie. Having solved the problem of the fish supply, the next question is that of the water in which the fish are to be planted, and the greatest trouble is the pollution of various kinds which the increase of population has caused to run into the streams.

In the economy of nature there are no waste products, but a system of balances. Take an aquarium for instance where the fish breathe the free oxygen and give off carbonic acid. Put sufficient plants in the aquarium and they take up the carbonic acid, use the carbon to build up their structure and restore the free oxygen to the water for the fish again to use. There is not a waste product that runs from a manufacturing plant that could not be utilized in some way, though perhaps under present methods not economically. A number of years ago the Supreme Court of Pennsylvania decided that as coal was a prime necessity and to mine coal the mine water must be pumped from the mines and until some method was devised to have water run up hill, mine water must run into the streams. Recent court decisions, however, have a trend towards changing this, because public policy and the needs of pure water supply are paramount to anything else, and therefore the mine water problem may have to be solved by the mine owner in the near future.

*Commissioner of Fisheries, State of Pennsylvania, Harrisburg.

Col. Roberts' paper shows that in addition to fish life being destroyed by the acidity of the discharges into the Monongahela River, much damage is also done by it to the machinery, pipes and other properties of the boats navigating the stream. This suggests an interesting question: Whether the destruction wrought to fish life and to the navigation interests is not greater in value than the savings made by the manufacturers in discharging their wastes, and if this is true, undoubtedly public policy will demand that the lesser interests must give way to the greater.

It appears from Col. Roberts' paper that the acids from the manufacturers can be utilized even at the present time, and undoubtedly practice and experiment will show that these wastes can be economically manufactured into products of value. It is not so long since that cotton seed was considered as a waste product, expensive to separate from the cotton, yet the wizards of the manufacturing world have now so utilized the cotton seed in various ways that its value is almost equal to that of the lint itself.

[It is desired to acknowledge the courtesy of the Technology Department of the Pittsburgh Carnegie Library in preparing the following. —Editor.]

LEGISLATION CONCERNING THE DISPOSAL OF ACID WASTES IN RIVERS

Choate, Charles F., Jr. The pollution of waters at common law and under statutes. 21 p. 1908. (In Journal of the Association of Engineering Societies, v. 40, p. 53.)

General discussion of present status of legislative practice.

Goodell, Edwin B. Review of the laws forbidding pollution of inland waters in the United States. ed. 2. 149 p. 1905. (United States Geological Survey—Water Supply and Irrigation Paper, No. 152.)

Summarizes the common law on the subject of water pollution, then abstracts the statues enacted by various state legislatures. Groups the states in three classes according to their legislation on the subject.

Class I. States which confine themselves to prohibiting certain ways of poisoning waters of streams or pollution in certain localities.

Class II. States in which legislative acts recognize the importance of pure water for every inhabitant for drinking and domestic purposes, but laws are general in application.

Illinois. "Whoever wilfully and maliciously defiles, corrupts or makes impure any spring, or other source of water or reservoir . . . shall be fined not exceeding one thousand dollars or confined in a county jail not exceeding one year". Another section makes it a public nuisance "to corrupt or render unwholesome or impure the water of any spring, river, stream, pond or lake to the injury or prejudice of others."

Indiana. "It shall be unlawful for any person, firm, or corporation owning or operating any manufacturing establishment to discharge or permit to be discharged into any stream of water any waste water or refuse from said factory of such character as to pollute said stream, except by and in pursuance to a written permission so to do, first obtained from the State Board of Health as hereinafter provided."

Ohio. "Whoever intentionally throws or deposits, or permits to be thrown or deposited, any coal dirt, coal slack, coal screenings, or coal refuse from coal mines, or any refuse or filth from any coal-oil refinery or gas works . . . upon or into any of the rivers, lakes, ponds or streams of this state, or upon or into any place from which the same will wash into any such river, lake, pond or stream . . . , upon indictment and conviction in the county in which such coal mines . . . are situated, shall be fined in any sum not more than one thousand dollars nor less than fifty dollars.

Class III. States that have adopted stringent methods of preventing the pollution of natural waters.

Pennsylvania. "No person, corporation, or municipality shall place, or permit to be placed, or discharged, or permit to flow into any of the waters of the state, any sewage, except as hereinafter provided. But this act *shall not apply to waters pumped or flowing from coal mines or tanneries*" . . .

In a case brought under the common law of Pennsylvania (Sanderson v. Pennsylvania Coal Co., 113 Pa. St., 126), the opening of a coal mine up the stream and the flowing of the mine waters into the stream rendered the waters unfit for domestic use. "In the final decision the court refused damages to the riparian owner. The reasoning of the court indicates that this result was due to its unwillingness to impose upon the immense coal-mining interests of the State the burden of paying for the damage to property in the water of streams caused by their operations; but the reason given

for the decision, in the court's attempt to harmonize it with the principles firmly established by precedent in Pennsylvania, was that the water which the defendant conducted into the stream was contaminated only by the coal, which was a natural product, and hence was said to be conducted into the stream in its 'natural state' ". . . . "But in subsequent decisions the courts of Pennsylvania have been careful not to extend the force of Sanderson v. Pennsylvania Coal Co. beyond the single act of turning the natural drainage from a mine into a stream."

MAXWELL, W. H., and BROWN, J. T. Law as to trade effluents, 400 w. 1910. (In their Encyclopedia of municipal and sanitary engineering, p. 474.)

Briefly shows tendencies of laws concerning the discharge of trade wastes into sewers and the regulations of different cities.

MOORE, E. C. S. and SILCOCK, E. J. Local acts of Parliament (concerning) disposal of trade refuse. 9 p. 1909. (In their Sanitary engineering, v. 2, p. 735.)

Cites extracts from the Halifax Corporation Act, 1905, as illustrative.

NAYLOR, W. Trade wastes. 267 p. 1902. Discusses (p. 1) legislation in England under the "Rivers Pollution Act", and argues that a change in the method of administering it is called for. Gives suggested standards for limits of polluting liquids, as "Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1000 parts by weight of distilled water."

POLLUTION OF STREAMS. 3000 w. 1909. (In Engineering Record, v. 60, p. 157.)

Summarizes results of additional legislation since report by Goodell in 1905. Reports that the Ohio State Board of Health indicates marked progress in purifying the streams. Indiana's new law forbids pollution of streams and places its enforcement in the hands of the State Board of Health.

PRATT, R. WINTHROP. State protection of the purity of inland waters. 30 p. 1907. (In Journal of the Association of Engineering Societies, v. 39, p. 199.

Summarizes laws on the subject in England and America.

England. Laws based on Public Health Act of 1875 and Rivers Pollution Prevention Act of 1876. "These acts prohibit the discharge of sewage, refuse and manufacturing waste into any stream where the purity and quality of the water would be affected thereby".

RAFTER, GEORGE W., and BAKER, M. N. Sewage disposal in the United States. 598 pp. 1900.

Appendix I (page 569) gives the text of the English Rivers Pollution Act of 1876. In the case of manufacturing and mining wastes, an exception is made in regard to mine drainage, which may be discharged directly into a stream (page 570).

SACKETT, ROBERT LEMUEL. Strawboard waste: its damage to water resources and its economic disposal. 35 p. 1905. (United States Geological Survey—Water supply and irrigation paper, No. 113.)

States on p. 10 that "the drainage from mines may also be offensive, but these are not usually amenable to pollution laws. In England they are specifically excluded in the rivers pollution act of 1876."

STABLER, HERMAN. Stream pollution by acid iron wastes; a report based on investigations made at Shelby, Ohio. 36 p. 1906. (United States Geological Survey—Water supply and irrigation paper, No. 186.)

On page 9 cites charge of the judge in a case in Ohio, in which the rights of riparian owners are defined, and the status of river pollution under the common law.

SMOKELESS COMBUSTION OF BITUMINOUS COAL IN THE PITTSBURGH DISTRICT

By Mirabeau Sims*

It is not the object of this paper to enter into a discussion of this most interesting subject in a technical or laboratory sense, but rather to present a few well known facts in a concrete form, which it is hoped will spur into action, with a laudable desire to excel, that body of plant physicians, known as mechanical engineers, and that their activity will eventually bear fruit in the shape of increased earnings, or rather additional savings, to the manufacturer and investor and confer a sense of duty well performed to the minds of this corps of first aid—the mechanical engineers.

The natural fuel for any particular district to use, is that which is most available, exists in largest quantities and costs the least laid down on the purchaser's premises, other things being equal. As bituminous coal, both run of mine and slack of about 13 000 B t. u. and eight to ten percent ash appears to describe local fuel, this paper will not treat of semi-bituminous or anthracite coal as they are in no wise germane to the subject matter.

We hear and read, more or less, about smokeless combustion, and proposed or enacted legislation, to eliminate, or at least materially lessen what is familiarly termed the "Smoke Nuisance"; but the field is, as yet, virgin soil, for what slight advances have been made in this direction have been of an unsatisfactory nature, or at best mediocre and more or less spasmotic. The elimination of smoke troubles in connection with the "City Beautiful" movement, while of a commendable char-

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acter from a civic pride point of view, is not and can not hope to be a solution of this problem. The elimination of the smoke in the Pittsburgh District will never materialize as a result of legislation, now in force or proposed, nor in connection with any "City Beautiful" movement however commendable; but it will certainly come and in a very plain, logical and matter of fact manner, and in the final analysis it will simply be a matter of dollars and cents and here is the writer's theory as to How, When and Why.

Pittsburgh is manifestly a manufacturing district and while its products are not of as diversified a character as in some of our larger cities particularly in the East, still in the aggregate they are, reckoned in money values, far greater. Pittsburgh's great manufacturing wealth and its inestimable value to the country at large places it in a peculiar and distinctive class and moreover as its vast industries depend almost wholly for motive power upon a smoke producing fuel, it is not difficult to understand why the problem of smokeless combustion in this locality is too great, too intricate and too closely interwoven with the wealth producing interests to lend itself to a simple and easy solution.

As no government is, or can be, better than its citizens so no law is better than its authors and while this assertion is not intended and must not be construed in a derogatory sense to Pittsburgh, yet it is none the less true and applicable to our city and any law which is, or proves to be, inimical to the interests and welfare of the body politic, will either be repealed or become a dead letter upon the statutes. Any ordinance enforcing smokeless combustion simply as a means to eliminate the smoke nuisance, will be observed in its breach rather than in its enforcement. The lay mind may consider the advantages of a "smoke consumer" or a device for absorbing smoke, but the mind of the mechanical engineer strikes at the root of the evil for it is a well known fact, and I make the statement without fear of contradiction, smoke cannot be absorbed or consumed. It may be dispelled, diluted, disseminated, but not consumed. There is in use in a large power plant in this city a, so called, "smoke consumer" and aside from sending the exhaust steam

up the stack and discoloring the smoke, its functions are nil and further comment would seem superfluous except to remark that this method of disposing of exhaust steam is not only novel but is uneconomical

The question as to how we can get rid of smoke is a pertinent one and the most natural answer: "Do not make it and we will not have any to get rid of", simply points the way but does not dispose of the matter. What causes smoke? Imperfect combustion. How can we secure perfect combustion? By supplying the right amount of air to the fuel under the proper conditions and this constitutes the entire problem of combustion. The results will be more or less perfect depending upon the degree to which theoretical conditions are approached.

Men are of many minds and while one may show a predilection for some particular object and strive in every manner to obtain it, his friend and neighbor will marvel at his peculiar ideas and candidly inform him he would not have the object as a gift. This, in a measure, is likewise true of different engineers' ideas concerning the various methods and devices for properly burning coal under a boiler. Chronologically, and to the writer's mind in point of merit, we have the ordinary fixed grate, the rocking grate, the chain or revolving grate, the overfeed natural draft stoker, and the underfeed forced draft stoker; these all have some points of merit and each has its advocates and adherents. It is not the purpose of this paper to discuss the relative merits of the various stokers and devices mentioned, except in so far as they pertain in a general way to the subject of smokeless combustion. There are stokers and stokers and while the writer may entertain some personal ideas on this subject, that is another story and will keep to a later date.

Kents handbook informs us that the theoretical ratio of air and fuel to obtain perfect or complete combustion is 12 lb. of air to one lb. of combustible. One of the largest firms in this country engaged in the manufacture of fans, advises specifically 18:1. Many engineers, who have made a study of this subject, agree on from 14 to 16 lb. of air to one pound of fuel (bituminous coal) as giving the best results in actual practice and if say 15 lb. of air per pound of coal is the proper proportion, then

the logical thing to do is to maintain this ratio under all conditions. For obvious reasons this cannot be accomplished with natural draft and we must apply mechanical means to insure a constant ratio. If atmospheric conditions were always uniform, if one could always obtain exactly the same grade of fuel and if there was never a fluctuation in the load and never a call for power, other than precisely the builders rating of the boilers, it would simply be a matter of figuring the proper grate area and stack dimensions. Instead of these ideal conditions, we are confronted with a daily loss in Pittsburgh of over 1 500 000 cu. ft. of good coal, a quantity which in the course of a single generation, would bury the entire city of Philadelphia (about 60 sq. mi.) to a depth of about six feet, and all due to our fatuous dependence upon natural draft. Why should we be so frugal with air, which appears to be inexhaustable and so profligate with fuel to the supply of which there must surely be some limit?

In the writer's opinion and he unhesitatingly makes the statement, forced draft and a mechanical stoker with the underfeed principle is the proper method to obtain smokeless combustion in actual plant practice. Is smokeless combustion attainable with bituminous coal? The writer most certainly thinks so and ventures to say that it will be secured in the near future. It is the fact, even now, within our reach as it is largely a matter of the application, and a very simple application at most, of natural laws. Consider a mechanical stoker of the underfeed or bottom feed type feeding continuously at a given rate a very thin layer of coal over the entire grate surface, with a slight racking motion imparted to keep the bed properly agitated and introducing the requisite amount of air at the bottom of the fuel bed with each thin layer of coal as it enters the combustion chamber, the supply of air and fuel being automatically controlled and the proper proportions maintained at half load, full load and overload, so that we get a well defined layer of green fuel on the bottom and on top of this a strata of coke and on top of this again an incandescent layer of fuel, discharging automatically all ash and clinker at the rear or bridge wall with no hand stoking or slicing of fire required. Under these conditions

smokeless combustion becomes a reality instead of a desideratum. And, further, the writer does not think it wholly a flight of the imagination to hope to attain 80 percent efficiency at 200 percent of builders rating, not in the sense of simply a test but rather as a steady diet. In fact, there are authenticated records of 76 percent efficiency at 230 percent of builders rating and this was and is now being accomplished with an underfeed, forced draft stoker, which projects the fuel into the furnace on the battering ram principle, rather than in thin layers as is believed by the author to be the proper method. We have in our city a record of 68.88 percent efficiency and 210.5 percent builders rating, using as fuel, Pittsburgh slack of 13 202 B. t. u. heat value. So it again appears to be largely a matter of application and when we consider and fully realize the utter futility and absurdity of burning every other day a lump of coal nearly as large as the 24 story Farmers Bank Building simply to produce smoke, we appreciate the vast import of this problem.

Smokeless combustion will surely be attained, but it will appear as an effect, or incidental, rather than as a cause, and the final, or acid test, will be a question of dollars and cents and not a Utopian scheme. Why talk to the manufacturer and investor in the dialect of the laboratory, bristling with CO_2's and calorific values, when the desired end may be so much more easily attained by arguments in the sign manual of all classes—dollars and cents

From the most reliable statistics obtainable, Pittsburgh and its contiguous territory within a radius of 50 mi. have in operation under normal trade conditions about three and one-half millions of boiler horse-power, entirely dependent upon bituminous coal as a fuel or a steam producing medium (this does not take into account, gas, or oil fired, or waste heat boilers) and if we allow say four pounds of coal per horse-power hour and 12 hours as the average daily run, we have the total 168 000 000 lb., or 84 000 tons, or 3 360 000 cu. ft., a lump of coal about as large as the Farmers Bank Building, consumed in this district daily at a cost of about $1.25 per ton or $105 000 for fuel (bituminous coal) between sunrise and sunset.

Now consider the ordinary method of hand firing as prac-

ticed today with the usual class of firemen obtainable for this grade of work and whose standard of selection appears to be brawn instead of brain and bearing in mind the average percentage of evaporation is about six pounds of water per pound of coal, or a trifle under 40 percent efficiency, out of a possible or theoretical evaporation of 14 lb. of water per pound of coal of 13 500 B. t. u's from and at 212 deg. fahr compared with a possible and highly probable 80 percent efficiency obtainable with the proper modern fuel saving devices, principally the mechanical stoker, and we find we have burned to no useful purpose whatever 50 percent of the total consumption of coal or in round figures $52 500 for every working day, as a burnt offering to maintain for our great business district, the unenviable cognomen "The Smoky City". This is $15 700 000 per year, $52 500 per day or $1.21 for every second of the day.

It was the writer's privilege recently to be present at a demonstration conducted in this vicinity, under the auspices of a Research Bureau showing how bituminous coal could be hand fired under a boiler and yet have smokeless combustion, with natural draft. Mechanical engineers, I find as a rule, are either natives of Missouri or direct descendants of the original settlers of that now famous State, and the fact that the natural draft at this test proved to be a well defined induced draft in the shape of a fan and engine, in no wise escaped their attention. With a cold or dead boiler of 210 h. p. (water tube type) and a good grade of Pittsburgh slack of about 13 500 B. t. u's, fire was started at 9:38 A. M., the coal being coked on the fore-plate and gradually worked back on the fixed grate bars, a shovel full at a time, by a fireman who evidently was selected for the occasion. With the fan running and the charging doors about one-third open, three-fourths of the time, steam pressure began to show on the gauge at 10:15 and at 10:38, just one hour after lighting the fire, the gauge indicated five pounds of steam, and at 11:02 A. M. the gauge showed 100 lb. pressure, at which time the steam was turned into the header leading to the engineroom. One of the visiting engineers estimated the amount of air entering the firebox to be between 30 and 40 lb. per pound of coal. The test though not entirely smokeless was a very close ap-

proach to it. Some of the visitors present remarked upon the sacrifice of economy in admitting so great an excess of cold air and the unusual lenght of time required to get up steam. As far as the writer was able to learn, the answer made was: It was not that kind of a test, but was simply made for smokeless combustion. I am free to say that it proved conclusively that bituminous coal can be burned under a boiler (hand fired) without making any smoke to speak of, provided one has plenty of fuel and is not pressed for time, but for all practical purposes it only goes to prove that we must look to the mechanical stoking of coal with a positive or forced draft as the solution of the problem. At a comparatively recent date a manufacturer placed an order with a well known stoker company for twelve mechanical stokers to be placed in his power plant under twelve 150 h. p. hand-fired boilers and in due season the plant was turned over to the owner as completed and paid for. I will add that the stokers were of the avalanche or overfeed type with natural draft; each boiler having its individual stack with no smoke breeching, 30 in. diameter and 60 ft. high.

A few days ago the writer was invited to visit this installation of stokers. Upon approaching the works he noticed at short intervals a heavy dense smoke issuing from each stack in quick succession, but only of momentary duration. He also noticed riggers at work on the twelfth or last stack, placing in position an extension of 24 ft. on each stack. When asked his opinion of the results being obtained he expressed his surprise at seeing so much smoke and said there must be something radically wrong. "Are you forcing the boilers beyond builders rating?" "No", came the reply, "We have not as yet been able to get over 80 percent of the builders rating but we have been able to reduce the firemen from twelve to six." The recording steam gauge showed a variation from 60 to 115 lb. between 10 and 11 o'clock A. M. The plant is operated 24 hours per day. The six firemen were kept busy with slicing bars poking up the fires on the steeply inclined grates (six inch fuel beds) with the front doors wide open while so doing, which explains the gushes of smoke from the stacks. The owner stated that the stacks had been extended 24 ft. at the suggestion of the stoker company

to provide more draft and in the event this did not prove sufficient, he was advised by them to take down the present stacks and put up new stacks 40 in. diameter and 100 ft. high; yet with the old stacks 30 in. diameter and 60 ft. high and hand fired using the same grade of coal, they had obtained without any trouble the builders rating and also the usual dense cloud of black smoke when firing up.

Comment at the time seemed somewhat out of place, except to inquire what guarantees the stoker company had made to him in their proposal. He replied, "Upon close examination it looked to him as if the only guarantee made was to put the stokers in his plant at a certain price, barring strikes and other acts of Providence." The writer looked over his proposal and was forced to admit that they had lived up to their guarantee, which was about as the purchaser stated; that is to say, they had placed the stokers in his plant and there was no interference on the part of Providence. As a compilation of meaningless words and intricate phraseology with a wholesome sprinkling of statements as to what the purchaser must do, etc., that proposal was a masterpiece and it served in a measure to elucidate the truth of that old axiom, "Language was given us that we might conceal our thoughts".

As a horrible example the writer would cite a recent call made at a manufacturing plant not so far from the city as to be out of the 50 mile radius and very near a coal mine, where the coal runs about 14 800 B. t. u's. They have in service four water tube boilers of 300 h. p. each, under which they have four stokers of a well known make, natural draft, using run of mine coal, operating 24 hours a day, with a fairly constant load. The stokers have been in service for about nine years and their ash dump has been used for filling up a depression on their property. As a rough guess this dump was estimated by the writer to contain in green fuel, which had sifted through the grate bars and showing no sign of fire, and good coke which had been dragged overboard before being consumed, about 50 percent in bulk of the total dump. I was informed that an average analysis showed 42 percent. The dump measures 210 ft. wide, 500 ft. long and 30 ft. deep, and allowing 30 lb. per cu. ft. and 40

percent good fuel making 37 800 000 lb., they have enough coal on hand to run their plant 328 days without buying another pound of fuel. They have since installed an additional 300 h. p. boiler and are now starting in to burn the ash heap under it, handfired. The moral of this story is "Beware of the law of diminishing returns" and they seem to have been perilously near unto it.

This brings to the writer's mind the apparent necessity of some action upon the part of mechanical engineers in general, perhaps your Society in particular to formulate a set of standard specifications for mechanical stokers. Do not misunderstand his meaning or misconstrue his intentions as trying to direct your action in any sense whatever, as he simply wishes to make the suggestion. Would it not be worthy of consideration to have this Society draft a set of specifications governing the standardizing of mechanical stokers to be known as the Pittsburgh Standard or perhaps better still the Engineers' Society of Western Pennsylvania Standard. This might well be on a cumulative basis, totaling 100 points; allowing say 50 points for 80 percent efficiency 20 points for 100 percent overload above builders rating, 10 points for not exceeding five percent of power generated to operate stoker and blower, 10 points for not exceeding $25 for cost of repairs per stoker per year, and 10 points for 95 percent smokeless combustion, or some other ratio of percentages which may deem just and equitable. Recommend a maximum, fixed price per horse-power, per unit of 250 h. p., for installation of from 500 to 1000 h. p., and larger installations in proportion. It will naturally be said that the stoker manufacturers would have something to say about this; very true, but this does not alter the case in the premises, and as such action would be placing a premium upon excellence of design and service, it will simply resolve itself into a case of the "survival of the fittest" and the stoker manufacturers will get into line or get out. It reverts back to the law of supply and demand and it is not so much of a problem to meet the requirements of the trade, be they ever so exacting, as it is to find the man who really knows what he wants and why should not a mechanical stoker be sold to pass a standard as much so

as a boiler to pass the Hartford Fire Insurance or a stockless anchor to pass Lloyd's Inspection? This does not mean that the buyer will have only one make of stoker from which to select, but it does mean that he will be reasonably assured of value received and he will get a *smoke preventer,* not a *smoke maker.* In many cases, the purchaser of stokers needs some definite pattern to follow in making his selection and still more in some cases, the purchaser should have some protection against himself; some insurance against his more or less excusable ignorance. For example, a purchaser complains about the unsatisfactory work of his stoker and when asked, why he did not put in forced draft replied he really wanted to, but he was advised not to do so, as the forced draft would overload the boilers and cause them to explode. When asked where he obtained this new and startling information he replied with the utmost candor, that the party who sold him his overfeed stoker told him so.

Just here is where engineering societies for the uplift of their enviable reputation, if for no other reason, can prove of great value to the buyer, as well as to the seller. We have accepted standard specifications for steel plate, rails, etc., likewise for fuel oil, concrete, steel cable, and copper wire, coal and coke are sold on analysis; iron ore is priced on the unit of metallic iron and many of the articles of commerce are bought and sold upon certain standards and this has been brought about by the concerted action of different bodies of engineers, acting in harmony with the manufacturer and consumer and largely within the recollection of the members present.

A committee might be appointed to draft a standard set of specifications for mechanical stokers, to be later approved by the Society and these could be printed and published in the mechanical journals and sent to engineers throughout the country, or incorporated into ordinances for the abatement of the "Smoke Nuisance" in various localities, or both methods can be pursued. It is a campaign of education and it will most likely be found that the man who contemplates spending from $1 000 to $50 000 for stokers, will be quite keen to improve his education, especially when he learns that his tuition is gratuitous and his tutors are a body of especially trained mechanical en-

gineers, striving in a common cause to not only eliminate the much discussed smoke nuisance, but to enable manufacturers to get better value on their investments, to better their output and to economize in the cost of same, as well as to conserve the bountiful store of fuel at our doors, given us by a beneficent Providence, rather than to exhaust their time and energy in a ceaseless hunt for a further source of supply and perhaps different character of fuel, rendered necessary by our profligate and unintelligent waste of that which we now have in apparent abundance at our hand.

[A partial bibliography of the subject of smokeless combustion is appended. Editor.]

Breckenridge, L. P. How to burn Illinois coal without smoke. 45p. 1907. (University of Illinois—Engineering Experiment Station. Bulletin No. 15.)

Shows principles underlying perfect combustion. Describes arrangements of furnaces, stokers and boilers for obtaining this.

Breckenridge, L. P. Smoke and smoke prevention. 8000w. 1909. (In Proceedings of the American Water Works Association, v. 29, p. 316.)

Explains principles of smokeless combustion, shows the Ringelmann scheme for estimating the relative blackness of smoke, and describes types of furnaces and boilers.

Coes, Harold V. Smoke prevention or smoke consumption. 11,000w. 1909. (In Engineering Magazine, v. 37, p. 395, 517, 745.)

Explains cause of smoke and principles of smokeless combustion, describes devices for use with handfired furnaces and mechanical apparatus for boiler firing.

Frary, H. D. Smoke prevention in steam boiler plants. 8000w. 1910. (In Minnesota Engineer, v. 18, p. 71, 144.)

Analyzes the causes which allow the formation of smoke. Describes and illustrates furnace, stoker and boiler arrangements for its prevention.

Hubbard, Charles L. Smokeless combustion. 4,500w. 1908. (In Electrical Review and Western Electrician, v. 53, p. 858, 903.)

General review of principles, showing effect of varying supply of air, care in stoking, etc.

Klocker, Dr. Zur frage der rauchverminderung im industriebezirke. (On the question of smoke reduction in industrial districts.) (In Stahl und Eisen, Feb. 3rd, 1909; p. 170.)

Describes methods and apparatus used in reducing smoke in industrial communities.

Knowlton, H. S. The new smoke law in Boston, Mass. 2200w. 1910. (In Engineering Record, v. 62, p. 150.)

A resume of the investigation made by the Boston Chamber of Commerce and the main features of the ordinance.

Lewes, Vivian B. Smoke and its prevention. 7,000w. 1910. (In Nature, v. 85, p. 290.)

Lecture before the London Institution.

Discusses physical and chemical action during combustion, and method of formation of smoke. Author favors the use of smokeless solid fuel, from which the smoke-forming constituents have been volatilized.

Parr, S. W., & Francis, C. K. Modification of Illinois coal by low temperature distillation. 48 p. 1908. (University of Illinois. Engineering Experiment Station. Bulletin No. 24.)

Investigation of changes in the chemical composition of coal that "would modify or minimize the production of smoke".

Porter, Horace C. & Ovitz, F. K. Volatile matter of coal. 56 p. 1910. (United States Bureau of Mines. Bulletin No. 1.)

Showing the bearing on smoke production of the volatile matter in coal.

Randall, D. T. Burning of coal without smoke in boiler plants. A preliminary report. 26 p. 1908. (United States Geological Survey. Bulletin No. 334.)

Reviews principles of smokeless combustion, proper furnace equipment and difficulties to be overcome.

Randall, D. T. Problem of smoke abatement. 4,500w. 1910 (In Power and the Engineer, v. 32, p. 2037.)

Abstract of paper before joint meeting of Boston engineers.

Shows that smoke is the result of the volatile matter in bituminous coals. Discusses design and operation of automatic stokers, and the use of steam jets.

Randall, D. T., & Weeks, H. W. Smokeless combustion of coal in boiler plants, with a chapter on central heating plants. 188 p. 1909. (United States Geological Survey. Bulletin No. 373.)

Records of experiments at 284 individual plants in the bituminous coal region of many states. Investigations include plants with mechanical stokers and hand-fired furnaces. Coals used were from many localities.

Smoke abatement. 8,500w. 1911. (In Journal of the American Society of Mechanical Engineers, February, 1911.)

Topical discussion, opened by D. T. Randall, on designs of furnaces and stokers, smoke observations by the Ringelmann chart, etc.

Smoke prevention. 7,000w. 1911. (In Proceedings of the Engineers' Club of Philadelphia, v. 28, p. 52.)

Discussion opened by D. T. Randall. Types of furnaces are discussed.

Switzer, J. A. Economy of smoke prevention. 1500w. 1910. (In Engineering Magazine, v. 40, p. 406.)

Gives experimental data on the possible effectiveness and operating cost of steam-jet devices for the boiler furnace.

Wadleigh, F. R. Firing stationary boilers economically; instructions and suggestions on methods of firing, regulation of air supply, cleaning, kindling and banking fires, and smoke prevention. 7,000 w. 1908. (In Power and the Engineer, v. 29, p. 955.)

Instructions apply especially to Eastern coals and Eastern plants.

It is desired to acknowledge the assistance of the Technology Department of the Carnegie Library of Pittsburgh in the preparation of the above list.

DISCUSSION

Mr. J. A. Hunter*: I have listened with a great deal of interest to Mr Sims' paper on the subject of "Smokeless Combustion." This question has received a great deal of attention recently in most of the large cities where bituminous coal is used as a fuel. The civic organizations in most of the large cities throughout the country are working on some plan to beautify and make our large cities more healthful places in which to live. Large volumes of black smoke coming from chimneys of industries naturally receive their attention as one of the first things to go after. Consequently most of the cities have ordi-

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nances prohibiting smoke. On the other hand, the manufacturer who has boilers in use is anxious to improve the condition in his city, and would be pleased to abate the smoke. He has also given this question considerable thought because a chimney from which smoke is pouring is a good indication that there is a considerable loss of fuel due to improper combustion, although the actual loss, due to the particles of carbon, is probably less than one percent. of the fuel.

It does not seem to me that Mr. Sims has given enough thought to the practical difficulties. If only new installations were to be considered the problem would be easy, because then the type of boiler and stoker could be selected which would suit the space available and the conditions of the particular installation. It is not a question of the new installations which gives the trouble but the installations which have been in for years.

Most of these plants were installed at a time when the question of economy was of secondary consideration and smokeless combustion was not considered at all. Also most of the manufacturing concerns which are located in the city limits are very much crowded and cramped for space.

The only way to successfully prevent smoke is not to make it, i. e., the combustion in the furnace should be perfect enough to burn all the carbon. In general, we might divide the method of firing furnaces into two classes, namely, "Hand Firing" and "Mechanical Stoker Firing." Either of these methods will give smokeless combustion if all the conditions are right, but the problem of smokeless combustion with a hand fired furnace is very difficult. In the first place it requires a skilled fireman and for most installations a special furnace. This furnace would probably have to be of the "Dutch Oven" type with some form of Kent's Wing-Walls.

In Pittsburgh it is very hard to get good hand firemen, for the reason that most of the men who are intelligent enough to make skilled firemen can get higher wages and have more pleasant surroundings at some other kind of work. The ordinary fireman is generally a foreigner who understands very little English, and is in reality not much more than a coal passer.

Any of the mechanical fired stokers, if properly installed

and operated, will give smokeless combustion. In a great many cases, on account of the space available and the present settings of the boilers it is practically impossible to install stokers without rebuilding the boiler plant, so it is seen that the question of getting smokeless combustion is not so easily solved as one might think.

According to Mr. Sims, the waste of fuel in Pittsburgh is enormous, and large savings are possible by installing mechanical stokers to improve the combustion. He has shown very clearly in his paper the immense amount of money which could be saved, but if this question is to be looked at from the *dollars and cents* point of view we must consider the return on the dollars invested. In most cases there would be no question about the improvement in economy by installing mechanical fired stokers, but even with a stoker a great deal of skill and attention must be given or the economy will not be any better than with hand fired furnaces.

In general, I think we would be safe in figuring on a gain in efficiency by installing stokers. Just how much this gain would be would depend a great deal on the local conditions.

The installation of mechanical stokers practically requires an installation of coal and ash handling machinery. This is true because for all stokers the fuel has to be especially prepared or complete combustion will not be obtained. One might be fortunate enough to make a contract to purchase slack coal, but there is so great a demand for this kind of coal that it is not safe to figure on being able to purchase enough of it to operate a plant.

For example, let us assume the conditions as stated in Mr. Sims' paper and see what returns there would be on an investment for a 1000 h. p. plant. We will take the conditions as stated in his paper, i. e., a plant burning four pounds of coal per h. p.-hr. and operating 6000 hours a year with coal at $1.25 per ton. We will also assume that there will be a gain in economy of 7.5 percent. (this figure is higher than I believe would be obtained in most cases) by installing mechanical stokers and also a saving of about $1000 a year in boiler house labor. The plant would then consume 12 000 tons of coal a year

and the saving would be 900 tons at $1.25 equal to $1 125 and $1 000 in labor, making a total saving of $2 125.

In order to make this saving it will be necessary to install stokers of some improved type, a coal crusher, coal conveyor and ash handling machinery. To make this installation complete it will require an expenditure of at least $15 000. The saving as shown above will represent a gross return of 14 percent on the investment. From this saving of 14 percent must be deducted charges for interest, taxes, insurance and depreciation. If an allowance of five percent interest is made, 1½ percent for taxes and insurance, this will leave 7½ percent for maintenance and depreciation. For this class of machinery this is not a very large percentage for these items.

From this it is seen that the installation of mechanical stokers at a plant of this size is not a very good investment for the manufacturer. So that from the *dollars and cents* point of view there is not very much to appeal to him.

Mr. Sims strongly recommends the type of mechanical stoker which uses forced draft and the underfeed principle. There are some stokers of this type on the market which are reported to give very good results but I do not believe that they are superior to some of the other type stokers with natural draft, such as chain grates, etc. I note he quotes results obtained in a test in the Pittsburgh district. In listening to this paper one would infer that this test was made on a stoker of the underfeed forced draft principle. As a matter of fact the test quoted was made by Mr. William Kent on an overfeed stoker with natural draft. Mr. Kent also made another test on the same boiler in which he obtained an efficiency of boiler and furnace of 75.55 percent. I have in mind another test made at the Water Side Station of the New York Edison Company on a chain grate stoker with natural draft, using soft coal with a heating value of 13849 B. t. u. per pound dry coal, the boiler being operated at 134 percent of rating. An efficiency of boiler and furnace of 71 percent was obtained. Considering these results I do not think that it is possible to draw a definite conclusion and say that only one type of stoker will give the desired results. It would seem to me that the conclusion to be drawn

is that for each particular installation the conditions should be carefully considered and the type of apparatus selected which will give the best results for these particular conditions.

Mr. D. F. Crawford:* The smoke problem on railroads divides itself into three parts. First, the smoke from our power stations of various kinds. Those plants of course are susceptible of the same treatment as the other boiler plants covered in Mr. Sims' paper. In our modern plants we are installing usually water tube boilers with mechanical stokers of various kinds. We assume that where the boilers have been of sufficient capacity to take care of the work imposed upon them the stoker handles the load with practically no smoke, making the plants pleasant to use and pleasant to the people who live around the shops.

Probably the most difficult problem we have is the smoke made at our engine house terminals when the green fires are prepared for the locomotives before departure. We have found no way to even reduce the smoke to an amount sufficient to call it satisfactory. We have tried various kinds of so-called smokeless coals, low volatile coals, various kinds of fire kindlers, and we even installed at one of our engine houses a large smoke washing plant. The results of that are failure. We did not seem to have enough property to put the smoke washers on to wash the smoke. However some of our more ingenious colleagues have succeeded in washing smoke. My own experience of smoke washing makes me not suspicious of their results but at least prepared to question them. I give this experience as an evidence of what the railroads are doing to try to assist in reducing the amount of smoke in the cities. We are quite anxious to assist the citizens to get rid of the effects of smoke as our own property and buildings which are generally immediately adjacent to our tracks are affected by it.

The third problem is the locomotive. I was rather interested in Mr. Sims speaking of 200 percent of builders' rating, etc. With the locomotive we do not quite know what the builders' rating of the boiler is. All we know is that when we stand one on the ground to operate a pumping station or some-

*General Supt. Motive Power, Pennsylvania Lines, Union Station, Pittsburgh.

thing like that it seems to strangely lose a great deal of its power. It is something like 100 h. p. where we have been accustomed to getting 1000 to 1500 h. p. out of it when it is mounted on some wheels. That is a slight indication of what we are doing in forcing the boilers. I believe our Pacific type locomotive would be rated somewhere in the neighborhood of 375 to 400 h. p. on its heating surface, etc. But if we do not get 1500 h. p. out of it it is not hauling the heavier trains.

Of course you all know that a gentleman named Clark a great many years ago put some steam jets in a firebox. I think I have personally examined some hundred variations of the applications of those steam jets as smoke consumers on locomotives. The various cities in which we and other railroads operate require, sometimes rather emphatically in the shape of a fine, that we put these steam jets in. Usually after putting the steam jets in they become happy and satisfied. We are not. We have not accomplished what we set out to do. We have somewhat reduced and changed the color of the smoke, but that is not preventing it. The jets in combination with the brick arch and some air openings above the fire box do prevent the very heavy smoke. That is of course one object accomplished. We instruct our men in the proper method of firing a locomotive, and it is quite possible if you do not mind what you haul with a locomotive, to operate it smokelessly by hand firing.

In England last summer I rode some distance on a motor car beside a train on the Midland Railroad. The firing was smokeless. The locomotive was equipped with a fire door that had a dash pot. It took some time to close after the fuel was put in. I could tell by the slight smoke emission, and I timed the firing, and he put in about one shovelful of coal a minute. In our large Pacific type locomotives if we do not put in six shovelfuls of coal per minute we do not haul the maximum train, and six shovelfuls a minute do not leave much time for a dash pot to work. Hand shovel firing, which our engineering friends have advocated for locomotives, works beautifully with light trains. But locomotives of course are supposed to haul the maximum load, that is what we try to do with them, and consequently they make a great deal of smoke. That sounds

as though the locomotive smoke problem is rather hopeless. But I do not feel so. The Pennsylvania Lines and a number of other roads have been experimenting for a number of years with mechanical stokers. We have developed on the Pennsylvania Lines with some degree of success an underfeed stoker which we now have applied to 30 locomotives and are applying it to more. These locomotives are in regular service and have made some 2000 trips, so our information is not based on either theory or quick conclusions. We are using run of mine coal from the western part of Pennsylvania, the Pittsburgh District, Ohio, Indiana and Illinois. In our endeavors to use the coking coals east of Pittsburgh, the low volatile coals, we have not been so successful. But with the coals of this territory, extending as far west as the product obtained in Illinois, I can say that we have succeeded in burning as high as 200 lb. of coal per square foot of grate per hour, and we have succeeded in doing that without exceeding an average of No. 2 smoke on the Ringlemann chart. Ordinarily the smoke produced by a locomotive hauling a freight train hand fired and within the capacity of the fireman, the average smoke is No. 1½ on the Ringlemann chart, that is half way between No. 1 and No. 2. A train of the same weight, handled by the same class of engine and provided with the stoker referred to has frequently operated over the road with the average smoke of 0.4. That is less than half of No. 1. That is in freight service. In passenger service the smoke is about the same it is in freight, probably running 0.4 to 0.5. In few cases do we reach No. 4 or No. 5 smoke. We have been running locomotives hauling full rating train and having an average of about 0.5 smoke and at no time did we make No. 2, except when it was necessary to spread the coal and hook the fire, and that happens from one to eight or ten times per hundred miles in our present state of the experiments.

In the shifting service, we have two locomotives where they are at work continuously, and I feel sure I am violating no confidence when I give to the Society the figures given me by the smoke inspector, whose opinion I regard very highly both on account of the fact that he is not employed by the railroad and

second he is an experienced smoke inspector. The inspectors followed this engine 41 hours on different occasions of two or three hours each, depending on the kind of service, making a total of 9754 smoke observations. Of these observations 9150 were No. 0. 569 were No. 1. 21 were No. 2. 10 were No. 3 and 4 were No. 4. The locomotive was burning Illinois coal, which I should say is not quite so smoky as the general coal in this district.

We do not regard the device as perfect, in fact it seems to develop new ideas all its own every few days that make us modify and improve it. But we have made 2000 successful trips, where there was 100 percent of the coal handled by stoker, from the tender into the fire-box without the fireman handling it.

Mr. D. P. Morrison:* I am interested in smokeless burning of fuel for one reason, because the city inspector has been after me. I will say that we are getting smokeless combustion in some plants and not in others. The difference is not due to a difference in apparatus but in conditions. Mr. Crawford spoke of the overload capacity of a locomotive boiler. If we could have our furnace, stoker, grate surface, and all the elements in proportion to the proper amount of fuel which we intend to burn we would have but little difficulty. Our lapses from a perfect record are undoubtedly due to our effort to get more out of any boiler than it was designed for, and secondly of course to carelessness. I think the author of the paper was rather hard perhaps on both the hand fireman and also the stoker manufacturer but the fact remains that a good fireman can get good results with poor equipment and a poor fireman will get poor results from the best equipment. So we have the two elements to bring into line. I do not agree with the speaker in his standpoint that smokeless combustion is to come in the effort to save dollars and cents. One speaker has already brought out the fact that the possible saving in fuel we lose in the smoke itself, that is in solid combustible carbon is but one percent. If our managers are satisfied to lose some 25 percent in flue gases etc. in forcing the boilers and thereby save in first

*Electrical Engineer, Pittsburgh & Lake Erie R. R., Pittsburgh.

cost, in ground space, in equipment, etc., how can we expect them to stick at the small one percent we would save in the matter of the smoke itself.

But there is a greater element than the fuel saving, and our railroads, our corporations, our business blocks, are spending great sums of money to reduce the smoke evil because it is economical in the broad human sense of reducing dangers to health and the disagreeable atmosphere which we are all familiar with not only here where it is more impressive but in numerous other parts of the country. An eminent mechanical engineer has said "Smokeless combustion is possible provided the volatile gases be distilled slowly, that they be mixed intimately with hot air, that they be confined in a hot portion of the furnace, and lastly that they not be cooled until they have had a chance to be consumed." Notice all the emphasis is on a sufficiency of time and space. We all feel competent to discuss smokeless combustion along those lines. That brings me back to the point first suggested, that all the elements must be proportioned and that in the mad race of American life we do not push the equipment which we have beyond the point where the proper proportioning of elements can not be maintained.

Mr. Crawford told of results that to me were surprising, and must be to every one here tonight. That means that in the device which he has obtained he has a stoker which is inherently designed to burn fuel at a greater rate than anything possible that we have for use in a stationary boiler, and that as the art is progressing undoubtedly the stoker manufacturers will and are supplying to us devices which will burn instead of 20 pounds per square foot of grate surface, 30 pounds or 40 pounds and allow us to get the greater capacity out of our boilers and at the same time reduce the amount of smoke made.

Mr. W. E. Snyder*: In looking over the paper which was read this evening there are only two points which seem to merit discussion. One point is that a forced draft under-feed stoker is the ideal solution of the smoke problem; the other is that it

*Mechanical Engineer, American Steel & Wire Company, Frick Building, Pittsburgh.

would be advisable for this Engineers' Society, or some body of engineers, to formulate a set of specifications for stokers.

Referring first to the latter point, i. e. standard specifications for stokers,—it seems to me it would be simply impossible to prepare any such specifications for a stoker. Reference has been made in the paper to the effect that standard specifications are prepared for boilers, which is correct. However, these boiler specifications refer only to the design of boilers, with reference to their mechanical construction, and the strength of same to resist the steam pressure to which they are subjected in regular service. Standard specifications for boilers do not make any provision for their being set in such a way as to improve efficiency. There would manifestly be no use in any engineers' society devising standard specifications for stokers which would consider their strength, as in case a stoker breaks there is no serious accident such as occurs when a boiler explodes. The attempt to cover in standard specifications the matter of efficient generation of heat and abatement of smoke by a stoker introduces all sorts of complications over which the stoker builders have no control, such for instance as kind of fuel used; kind of boiler used; the arrangement of the furnace by which the stoker is connected to the boiler, etc. In other words, a stoker builder cannot by himself produce an efficient heat apparatus, for the reason that the results produced by the stoker must be measured by the results from another piece of apparatus, the boiler, with which the stoker builder has nothing to do.

Now in regard to forced draft. I read before this Society in 1899, a paper on the subject of Mechanical Devices Applied to Firing Steam Boilers†; and in that paper discussed this matter of forced draft to a considerable extent, as this method for burning coal by means of feeding it underneath the fire, and supplying the required air by means of a fan, was then under active investigation and impressed me very favorably. The discussion which I gave in that paper on this subject was of such a nature that one enterprising representative of an

†Proceedings, Engineers' Society of Western Pennsylvania, 1899, Vol. 15, p. 333.

under-feed stoker company bought several hundred copies of the PROCEEDINGS, drew red ink marks around the paragraphs which referred to under-feed and forced draft, and sent these marked copies out as advertising matter. From this it will be seen that I shared at that time the opinion of the writer of this paper, that a forced draft under-feed stoker installation was a very desirable one to make. Since that time, however, a more extended experience has caused a very decided change of opinion.

The basis of the forced draft discussion which was contained in my former paper was a series of tests made by feeding the fuel underneath the fire, the forced draft being supplied by a fan. The results of these tests indicated a very substantial saving in fuel over the hand fired conditions then existing, and a very apparent abatement of smoke. The installation was made, and after operating two or three years it became almost impossible to keep the stokers which supplied the fuel to the furnace, in practical operating condition. The repair costs were enormous; it was necessary to fire part of the fuel by hand; these conditions more than neutralized the advantages which were found in the preliminary tests, and the removal of these stokers became an absolute necessity, if the works was to continue to operate. I thus had the experience of showing a large saving by making the original installation, and then a few years later of showing a still larger saving by taking the installation out, so that possibly I ought to feel favorable to forced draft.

However, since that experience there have been developed one or two types of under-feed forced draft stokers which I understand are much more satisfactory. As I have had no practical experience with these newer types of forced draft devices, I shall not discuss them any further, and only mention them here in order that I may not be understood as condemning all forced draft apparatus because of the unfortunate experience which I have cited above.

The outline which I have just given of our experience at one plant in the endeavor to eliminate smoke illustrates one point which I wish to bring very prominently to your attention.

This point is, that no matter how favorably an installation may seem to operate in its economy and in its results in the elimination of smoke, there must always be kept in mind the question of continued reliability under practical operating conditions. The temporary elimination of smoke is not the only end to be achieved. It is the development of a set of conditions which will eliminate smoke, and which will remain permanent under the practical operation of the works. This is what I regard as the proper solution of the smoke abatement problem. So long as it is necessary to make observations of stacks every few hours or days, and hold conferences with owners of such stacks relative to the fact that on a certain date the stacks were smoking and two weeks previously they were smokeless, etc. the means being used are only palliative, and no cure is being effected.

To explain what I mean, I will give one concrete illustration. We have in Cleveland a works which is located near one of the city parks. There were originally in that works 28 return tubular boilers, 66 in. in diameter and 16 ft. long. These boilers were all hand fired, using either Pennsylvania or Ohio run of mine coal. Smoke was always produced, the only difference being that sometimes it was very much worse than at others. There was continued complaint on the part of smoke inspectors and others in the city, as the prevailing winds carried the smoke over the park. Various means were tried to prevent the formation of smoke, but without any success to speak of.

It finally became necessary to replace the boilers because of deterioriation; it was necessary to install boilers strong enough to withstand much higher steam pressure. Sixteen 300 h. p. Stirling boilers were installed, equipped with chain grates. Careful attention was given to all the details of the setting of the grates, boilers, flues and stacks, with the idea of eliminating smoke, and at the same time operating the boilers efficiently from a heat consumption standpoint. The results were that the plant has now operated for four or five years with practically no smoke at any time. It is hardly possible to tell whether or not the plant is in operation by observing the tops of the boiler house stacks from a distance. There has never been any

further criticism on the part of the City Smoke Inspector, or of any one else. The trouble was cured by eliminating the smoke entirely. It is not necessary to have a smoke inspector observe the stacks at frequent intervals and make formidable reports of various kinds. The point which I wish to make is that the conditions which brought about the elimination of the smoke are permanent in practical operation. When the changes that are made require nursing,—when somebody has to "inspect" the plant to see that the smoke that was eliminated is still eliminated, then the change is only a make-shift and the results will never be satisfactory from a smoke abatement standpoint.

The above example serves to illustrate very conclusively that smoke can be completely eliminated where the conditions are such that the plant can be completely renewed. We have duplicated this experience in other works which I need not discuss here. The main problem in smoke abatement is its complete elimination in plants which are still so good that they cannot be wiped out and replaced with modern equipment, set in such a way that smoke is never formed. It is these installations which are the most seriously perplexing to deal with. Judging from our experience at a number of works located in different parts of the country, it is not practicable to make such changes in many old boiler plants as will eliminate smoke permanently. It is not that the conditions requisite for the smokeless combustion of fuel are not known, but it is because it is not practicable to bring about the conditions required in many boiler plants that have been installed years ago, because of peculiarities of construction, of boiler settings, or the limited space, and numbers of other local conditions, which cannot be obviated without such large expenditures as render the changes prohibitory. This latter matter is discussed further later.

Every method which we have tried to eliminate smoke in old plants has proven to have its defects which make it practically unreliable and unsatisfactory. For instance in one plant in Illinois of 30 horizontal water tube boilers, originally set for hand firing, we installed chain grates exactly similar to those installed in the Cleveland plant that is described above.

Although we devoted special attention to the arrangement of the setting of the new stokers under the old boilers so as to eliminate the smoke as much as possible, the result has not been satisfactory as not more than 60 to 70 percent of the smoke has been eliminated. This is the result of the best arrangement that could be made, using old boilers of this type and new chain grates. While this reduction in smoke may be regarded by some as very satisfactory, I cannot so regard it, for the reason that to secure even this reduction requires continued driving of the men in charge of the operation of the boilers. That is, there must be continued and rigid supervision exercised to attain even a mediocre result and when the rigidity of the supervision is relaxed, the conditions immediately become worse. As I have emphasized above, any condition of this kind is not right, because it depends on the maintenance of an operating supervision which in many works it is not possible to exercise.

Another method which we have investigated for the prevention of smoke is that of the installation of dust fuel, or pulverizing the coal very finely before it is blown into the furnace. At one works where this was tried the economy of fuel was good. The conditions so far as smoke prevention was concerned, were very good, but the heat generated in the furnace was so intense that it was impracticable to obtain any furnace lining that would withstand it, and the result was that it had to be discontinued. At other plants where I investigated this method of using fuel, while it gave very good thermal efficiency and prevented smoke, a large part of the ash of the fuel which had been reduced to dust in the pulverizing process, was blown from the stack and distributed over the entire neighborhood, and was a worse nuisance than the smoke. At other plants we have installed the inclined grate stoker, or the type referred to by the author of this evening's paper as the "Avalanche Stoker." Nothwithstanding the best efforts that can be exerted in the practical operation of these stokers, we cannot make them smokeless; and so I might continue citing other instances if I cared to take the time to do so, all tending to show that with old boiler plants the effort to bring about smokeless conditions was most unsatisfactory. The difficulty is

that the changes which must be made are only palliatives, and do not cure the trouble. They may result in the partial or, entire elimination of smoke temporarily, but the results are not permanent. I do not assert that this is true of every plant of old boilers that exists, but I say it is true of the large majority of boiler plants which were installed without any thought of smoke prevention, and without much thought of fuel economy.

It is proper to say here that in new plants which are installed to prevent the formation of smoke, the use of damper regulators to maintain an approximately constant steam pressure may cause smoke to be formed at times. When the dampers are partially or entirely closed by the regulators, smoke is very likely to be produced. There is, however, no unfavorable criticism to be directed against the boiler plant because of this condition, as it is always within the power of the management to decide which of the conditions are most desirable, the frequent blowing of safety valves with the accompanying waste of fuel and variation in steam pressure, or the formation of some smoke at times. In addition to this it is quite probable that further investigation into the conditions will enable damper regulators to be used to maintain a fairly constant steam pressure, and at the same time keep the smoke produced down to a very low minimum.

It has always seemed to me that there was a great deal of unnecessary discussion and agitation on this subject of smoke abatement. A great deal of the effort seems to be directed to whacking at the conditions that now exist, while no effort at all is directed toward getting to the bottom of the trouble and permanently correcting it. The smoke agitation in Pittsburgh must have begun over 15 years ago,—possibly 20 years ago. If one experienced and capable smoke inspector had been appointed a year or two after the first beginning of the smoke agitation, with the advisory assistance of three or five good engineers, and the discretionary power to pass on the plans of all new boiler plants, etc.—from 50 to 75 percent of all the smoke now produced in this District would never be produced; it would have been permanently eliminated by the installation of such boiler

plants as would never make smoke. Of course, there is no use in reflecting now over "what might have been" had such a proceeding been adopted at the beginning of the agitation. It is, however, not a very good commentary on the knowledge of the persons who have been active in such an agitation during the past, to note that of all the smoke ordinances which have operated in Pittsburgh, not one had any proviso which gave the smoke inspector any preliminary supervision over new boiler plants when they were being installed. They were about as sensible in this respect as a Building Code would be which gave the building inspector no right to look over plans, but it gave him the right to prosecute the owner of the new building if it did not meet the requirements of the Code. During the past a little more study of what conditions were required to prevent the formation of smoke, and a little less effusion of oratory, would have gone far to mitigate the conditions that exist at the present time.

We have societies formed for the abatement of smoke, etc. somewhat as though the production of smoke was a serious disease like smallpox or tuberculosis that could be eliminated by the dissemination of knowledge among the general masses of the people at large. Of course, the idea is to form a public opinion which will be strongly unfavorable to the pollution of the atmosphere with smoke, but this is nothing but nonsense. There are no societies for the "Prevention of the use of Defective Boiler Plates", or the "Promotion of the Use of Steel Beams", etc. There does not need to be any such society to concentrate public opinion. The men who have to do with boiler plate, steel beams, etc. have of necessity made a study of the physical properties of the materials which they are using. Because of their knowledge of the conditions with which they are dealing, and because of their own reputations which they may make or break, depending on the results they achieve, we have boilers and buildings which are strong enough for the service to which they are subjected, without any public opinion being concentrated on the engineer one way or the other. The point which I wish to make is—that so long as the conditions are such that any one who wants to do so, can build a brick wall around

a boiler and a stoker, and put a fire under it, and use it to produce steam without any engineering supervision whatever,—just so long may we expect to have the smoke problem with us. It is an engineer's business to supervise the installation of all kinds of furnaces and apparatus which uses fuel or heat, and when such supervision is relegated to men who only know how to use a block and tackle and lay up brick, it is a foolish proceeding to make one of the results of such a custom the subject of a public agitation. The thing to do is to have such an ordinance as will prevent the installation of any kind of fuel using apparatus without detailed plans passing the approval of the head of this particular department, call him smoke inspector, furnace inspector, or what not—then the responsibility for results from a new installation is fixed.

There is nothing mysterious or difficult in the theoretical principles which govern the prevention of smoke. It is simply necessary to burn completely all the combustible in the gaseous products of combustion before these gases reach the comparatively cooler heating surface of the boiler. Since combustion is the combining of oxygen with the combustible elements of the fuel, it is necessary to make the conditions such that this combination will be completely carried out before the process is stopped. As this combination takes place only at high temperatures, it is necessary that the furnace should be kept hot; also as each particle of combustible matter must find its complement of oxygen in order to be burned, the air must be present and properly distributed. In order to maintain a high temperature, the combustion must take place in a chamber that is lined with brick-work on all sides except, of course, the one in the direction which the gases are moving; in order that all the particles of combustible matter may be oxidized, time is required. This time may be gained by making the section of the combustion chamber large, so as to reduce the velocity of the gases, and also making the combustion chamber long, so that the combustible particles will all find their respective oxygen molecules before the temperature is reduced enough to prevent the combination when the combustible and the oxygen particles come together. Sometimes where it is not possible to obtain the necessary length,

various other devices, such as wing walls, arches, etc., are adopted with the idea both of facilitating the mixture of the combustible matter and the oxygen, and also to increase the heat radiating surface, thereby assisting in maintaing a high furnace temperature. These are in general the conditions that are necessary to prevent the formation of smoke. A little study on this particular point will show why it is possible to obtain conditions in a new boiler plant which will enable it to operate practically smokeless, while with an old boiler plant it is practically impossible to ever obtain such conditions. This also emphasizes the necessity mentioned above of having the plans for all new boiler plants pass the supervision of some expert engineer who is familiar with the conditions that are necessary for smokeless combustion.

While there is nothing difficult or mysterious about the conditions which are necessary for smokeless combustion, it is in the application of these principles to all kinds of existing and operating boiler plants wherein the difficulty lies. It is not possible to make the conditions such that the fuel will be completely burned before the gaseous products of combustion reach the boiler. In very many boiler plants the combustion takes place immediately under the boilers. As soon as the gaseous products of the coal are distilled off they strike the comparatively cool surface of the boiler, and all the particles of gas which give up their heat to the boiler heating surface at this time are immediately cooled below the temperature at which they will burn. The result is that some of the combustible matter passes off unburned as an invisible gas, and the small carbon particles pass out to form what we call smoke. It may be remarked in passing that the heating value of the fuel that is lost as smoke is very small, but smoke is rather a sympton of incomplete combustion, and where there is smoke there is a strong probability that a much greater loss of heat occurs in the invisible gases escaping than actually occurs due to the particles of carbon carried away. Also it may be stated that in endeavoring to eliminate smoke from old boiler plants, there is sometimes so much excess air introduced that the heat loss due to the excess air far more than counterbalances the loss

previously due to incomplete combustion, so that the fact that a stack appears smokeless is no indication whatever that the boilers are working under good economical conditions.

This statement can be made regarding the elimination of smoke in old boiler plants: That where the local conditions are such that changes can be made which will permit the conditions necessary to smokeless combustion to be fully realized, smoke can be eliminated. However, where the local conditions are such that the necessary changes are impossible, or so expensive as to be prohibitive, smoke cannot be prevented. In plants coming under the latter head it is possible, of course, to eliminate some smoke, but very often the means which are adopted to do this are such as to really decrease the efficiency of boilers rather than improve it.

To sum up what I have stated above, it is possible to construct boiler plants to use Pittsburgh coal so that they will operate practically smokeless. The most effective time to abate the smoke nuisance is before any smoke is formed, that is when a new boiler plant is being installed, and every municipality which makes any attempt to stop the formation of smoke should begin by first exercising expert supervision over new boiler and furnace installations. With old boiler plants the results will almost always be unsatisfactory, especially as compared to the possible results from new plants if properly installed. Any changes in old boiler plants which make it necessary to inspect at intervals because last week the plant operated without smoke, and this week it is producing smoke, must be regarded as entirely unsatisfactory. The conditions requisite for the prevention of smoke are comparatively simple, and are known. If these conditions can be established in old boiler plants, the results will be good; if they cannot be established, no amount of battering or nagging on the part of any system of inspection will produce permanent results, which are the only results that have any right to be mentioned in an engineering discussion.

There has been handed to me this evening a copy of the proposed new smoke ordinance for the City of Pittsburgh. It would hardly be fair to discuss this ordinance without giving it

considerable study, and indeed it may not be advisable to discuss it in any event, for the reason that unless criticism can be constructive as well as destructive, it is not of much value, and I am not prepared to make practical suggestions for the points in the ordinance which I would criticise.

One particular point that I notice with appreciation is that the proposed ordinance provides that plans for all new furnace and boiler installations must receive the approval of the Chief Smoke Inspector. This is as it should be, only it comes about 15 years too late.

There are some inconsistencies which it would seem to me could have been eliminated, though as I have said before, I am not prepared to suggest a method by which this could be done. I refer particularly to the fact that the ordinance as it is drawn is directed especially against owners and operators of steam boilers. Heating furnaces, puddling furnaces, etc., are exempt from its provisions. Also the ordinance specifically prohibits the emission of dark gray or black smoke for a period longer than eight minutes per hour. Maybe this is the best that can be done, but it is not very good. A stack 24 in. in diameter emitting dark grey smoke is breaking the provisions of the ordinance, and the owner of this stack is liable to a fine. A large stack,—say 12 ft. in diameter, may emit light grey smoke for days and yet be within the safety zone. At the same time, the large stack may be distributing two or three times as much soot over the neighborhood as the small stack, yet it is within the limits of the law. I should like very much to see an ordinance drawn by a committee of about three experienced engineers, at least two of whom were practically experienced in the operation of a variety of boiler plants and heating furnaces.

Mr. Wm. Glyde Wilkins:‡ When I came here this evening I did not expect to say anything, but Mr. Snyder has made a statement which, as a member of the Council of the City of Pittsburgh which passed the Smoke Ordinance, compels me to get on my feet. He says that we ought not to harass the manufacturers. Council today passed an ordinance authorizing the Mayor to employ Mr. Holdsworth of the University of Pitts-

‡Civil Engineer, W. G. Wilkins & Co., Pittsburgh.

burgh to make an economical survey of the City. One of the things he is going to try to find out is the causes for the high cost of living in Pittsburgh. I do not think anybody will contradict me when I say that one of the causes of the high cost of living to every citizen of Pittsburgh is the smoke. I was at a town in the eastern part of New York State not long ago with my wife visiting a friend. We happended to notice in the rear room of that house a wall paper that we remembered was there twenty years ago. And it has not been cleaned once. In Pittsburgh I think every man here will admit that if he wants a clean wall he has to either renew the wall paper every year or clean it every year and after it has been cleaned three or four times you have to put on new paper because the old one is worn out. Why should a few manufacturers who do not want to go to the expense of putting in a proper boiler installation put everybody in their neighborhood to the expense of new wall papers or cleaning old wall papers every two or three years?

And not only that, but Mr. Frank will remember that when we were getting our education in Troy, if a man wanted to he could wear a collar a week without its being any dirtier at the end of the week than in Pittsburgh in one day. In Pittsburgh you have got to put on a clean one every day, if you want to look respectable. It costs two cents for laundering a collar, that is 14c a week and 14c a week for every man who wears a collar in Pittsburgh is a good deal of money.

Housekeepers are not only put to the expense of cleaning wall papers, but carpets, curtains, paints, clothing, etc., in fact, the smoke nuisance puts almost every citizen to unnecessary expense which he is not put to in other cities of the country. I do not believe that I am exaggerating at all when I say that I believe the additional expense put upon the half million people of Pittsburgh in one year by reason of the unnesessary smoke, is pretty nearly if not fully as great as it would cost the manufacturers and users of steam to equip their boilers with smoke preventing devices.

The City Council does not wish to drive manufacturers out of Pittsburgh, they simply want to make the manufacturer work

his boilers and furnaces under proper restrictions by which they will give fair treatment to the citizens of Pittsburgh and not put them to the additional expense that they have had to live under in the past when there was no smoke restrictions. Mr. Frank made a remark before the Council Committee that had this under consideration that struck me as being to the point. He said, "No manufacturer in the City of Pittsburgh has a right to dump smoke in your parlor any more than he has to dump garbage in your dining room". I think that statement morally speaking, might almost be called an axiom, as it needs no proof. The old ordinance, as Mr. Snyder says, was repealed because the Court considered it unreasonable. The Committee of Council that had this matter in charge wanted to prepare an ordinance that the courts would not say was unreasonable. We had hearing after hearing, and manufacturers and engineers appeared before us, with all sorts of advice. We also had for our guidance, the ordinances of most of the large cities in the country, such as Detroit, Chicago, and neither one of these cities allow black smoke even one minute. In order to be sure that the court would not say this ordinance was unreasonable the Committee put in eight minutes, as the time dense gray or black smoke would be allowed. I defy any good fireman to say that it is unreasonable. We do not believe that the court will say that the present ordinance is unreasonable. As far as the manufacturers of the City of Pittsburgh are concerned, I believe that after the ordinance has been in effect a couple of years they will admit that it is not unreasonable and that they will not object to cutting the eight minutes to four or three or possibly two minutes. I do no believe this ordinance will drive anybody out of the city. We as members of Council have tried to be fair both to the manufacturers and to the citizen and I believe time will show that we have been more than fair in the preparation of the present ordinance.

Mr. S. B. Flagg*: There are present many engineers who, in superintending plants under their charge, have collected data as to operating and maintenance costs with different types of power plant equipment and are in better position to discuss

*Engineer, U. S. Bureau of Mines, Testing Station, Pittsburgh.

this phase of the subject than is the speaker. For this reason, my remarks will be confined to some of the other phases of the subject.

Inasmuch as the author seems to have an incorrect impression as to the purpose of the demonstration mentioned in the paper, as well as to the conditions under which it was made, I desire to say a few words about this demonstration in order that others may not be misled by what has already been said.

First, as to the conditions under which the demonstration was given; the statement had been made that it was impossible to build a new fire under a cold boiler without violating a smoke ordinance permitting only six minutes' emission of dense smoke in an hour. A demonstration was therefore made in which a water-tube boiler set over a stoker of the underfeed type was used. Steam was raised and the boiler cut in on the line in about an hour's time after lighting the fire. During this time there was practically no emission of smoke—the ordinance had not been violated.

This proof was not entirely satisfactory to some of those who asked for the demonstration, because the boiler was mechanically stoked. At their request, a second demonstration was made on a hand-fired boiler in practically the same manner as the first one had been made, with results about as stated by the author.

Immediately after steam had been raised in this hand-fired boiler which operates with induced draft, a similar trial was made in a 75 h. p. tubular boiler. The latter is operated with natural draft and has plain grates. The fuel used was slack coal from the Pittsburgh seam. Starting with a cold boiler, steam was raised in a little less than an hour and full boiler pressure in a little over an hour, during which time the amount of smoke emitted was easily kept within that allowed by a six-minute ordinance.

During none of these trials was a gas analysis made and it is therefore, impossible to say what the ratio of air supplied to coal consumed was during this period of building up fires. That the fuel is burned with too high an excess of air under such conditions is certain, but the same may be said of prac-

tically all kinds of equipment during the time that fires are being built up.

The speaker does not wish to be understood as advocating the operation of hand-fired steam boilers in preference to using mechanical stokers. If our hand-fired plants could all be changed and stokers properly installed therein, it would not only be highly desirable from the smoke standpoint but the fuel cost of steam in such plants, would, in general, be considerably reduced. There are today, however, and are likely to be for some time to come, many plants without mechanical stoking equipment and their stacks will be among the most difficult to clear up.

Recognizing this fact, the Bureau of Mines undertook a series of tests on the hand-fired, return-tubular boiler before mentioned, to determine whether with such equipment it is possible to develop the rated capacity of the unit without exceeding the permissible amount of smoke. The results of these tests indicate that such a thing is possible, but that the stoking must be carefully done. Some of the features of the setting of this unit are recognized to be detrimental and it is believed that further tests with an altered design of furnace will show that it is not a difficult matter to burn coal from the Pittsburgh seam in the hand-fired boiler if some auxiliary mixing devices are used and the unit is carefully operated. Such a means of eliminating smoke, however, will always require more care and skill on the part of the fireman for its successful working than will be necessary in a mechanically-stoked plant, if the stokers are properly installed.

Because of the fact that for many years to come a large proportion of the steam plants in this, as in nearly every other, district will be hand-stoked, the present speaker is of the opinion that legislation will play an important part in bringing about the elimination of the present smoky conditions. The production of smoke, unless it be exceedingly dense, does not always mean that there are serious losses from incomplete combustion. Under such circumstances the operators of the plant may not suffer as serious losses from the production of the smoke as are sustained by the general public from its effects.

It is for this reason that legislation is required to bring about the necessary changes.

The effectiveness of such legislation is dependent upon two factors, the character of the enactments and the proper enforcement of same. It is obvious that no smoke ordinance should require the impossible, but it should set such a standard as the best practice shows can be attained, if it is to be effective. The enforcement of an ordinance is, of course, possible only when it is supported by public opinion, but in addition to this there must be the proper efforts upon the part of the officials charged with the duty of such enforcement. A spirit of co-operation should exist between these officials and the owners or operators of the plants, as better results will be obtained under such conditions than will be possible where there is a spirit of antagonism. At the same time a smoke ordinance is worthless if its provisions are not firmly and impartially carried out.

In closing, it is desired to call attention to one or two points about the new smoke ordinance for this city. Section 7 provides that "During the first hour in which a new fire is being kindled in or under a cold boiler or other furnace, excepting in private residences, mill heating furnaces and puddling furnaces, 60 min. once a day for the first year, 45 min. once a day for the second year, and 30 min. once a day for the third year, and each and every year thereafter of dense black or dense grey smoke issuing from the stack or chimney thereof will not be a violation of this ordinance; ——". Not only is this a decidedly liberal allowance of time during which dense smoke may be emitted, but in the case of a stack serving twelve boilers one hour's emission would be permissible after the starting of each and every fire. Moreover, the provisions of this section make it necessary, in order to prove that the ordinance has been violated, to show that no new fire has been built under any cold boiler connected to the stack within the hour. This greatly complicates the work of the Smoke Inspector's force and makes convictions more difficult.

In the matter of regulating locomotive smoke the ordinance is defective in that there are no provisions regarding the length of time smoke may be emitted, other than the eight minutes per

hour for regular operation and one hour when a new fire is being built. On account of the movement of locomotives, and the same would apply to steamboats, the stack could almost never be watched for an hour by an inspector, and could frequently not be watched for even eight minutes.

The proper regulation of the smoke emission could, in the speaker's opinion, be much more effectively carried out if no special provision were made for the period during which fires are built up. But if some such concession is deemed absolutely necessary it would have been better to increase the eight-minute allowance to say fifteen minutes during the hours when most fires are being built, viz: from 5:00 A. M. to 7:00 or 7:30 A. M. In this way the operator would not have a loop-hole to crawl through all day long, and the work of the Smoke Inspector would be greatly simplified.

The ordinance would also be strengthened if, instead of classifying locomotive and steamboat stacks along with the stacks of stationary plants, a violation were defined as the emission of dense black or dense gray smoke continuously for a period of one minute, or possibly one and one-half minutes. It would then be possible to determine when a locomotive violates the ordinance.

It is to be hoped that the present ordinance may before very long be so modified as to make it stronger in these points, as well as in some others, which I have not mentioned.

Mr. I. W. Frank:† I am not posing as a smokeless engineer but I have been interested in the subject of smokeless furnaces for about 30 years. I was much in the condition 30 years ago of many of our smoke makers in Pittsburgh today. The first smoke consumer I was induced to put in drew smoke out of the stack and put it under the grate with an additional quantity of air. The inventor showed me that the smoke we had produced would be consumed and consequently there would be no smoke. If we were making no smoke from our coal there would be no smoke to consume and consequently we would be putting fresh air under the boiler and would have induced

†President, United Engineering & Foundry Company, Farmers Bank Building, Pittsburgh.

draft. In fact that is what we did have and we got along pretty well. It was not such a foolish apparatus as it seemed at the start. But it did this for me. Having been away from Pittsburgh four years at Troy, which is a very clean city, and being able to wear a collar a week and a shirt likewise for the sake of economy, and coming back to Pittsburgh I found it in a condition that really needed something done. So that my earliest enlistment in the smoke abatement crusade in Pittsburgh dates back about 30 years. I have followed it up to this day and every plant I have had anything to do with, whether it was a matter of dollars or civic pride, I had smoke preventing apparatus introduced. Sometimes of the avalanche type, sometimes the chain grate, and sometimes the underfeed type, but in every instance I recognized an economy. The economy in some cases was not so great in fuel, but boiler repairs, due to the continuous firing of small quantities of coal properly fed with air was a positive advantage to the boiler installation. The excessive changes in boiler temperature in the furnace were avoided, and much more comes to a boiler plant in the way of advantage from a stoker than we are wont to give it credit.

I believe as manufacturers we should recognize our civic obligations and that the emission of black smoke is one of the crimes of the City of Pittsburgh. People outside of the city know us as the "Smoky City". We ought not to be known as the "Smoky City", we ought to be known as the "Hive of Industry", and we can be the hive of industry and still have a smokeless city. I am no stickler but I advocated smoke not to exceed No. 2 on the Ringlemann chart. There is not an engineer in the room but will say that he can operate a boiler plant, puddling furnace, heating furnace or any other type of furnace that requires a reducing flame, on No. 2 smoke. You can stop the oxidation of iron just as well with No. 2 smoke as with No. 4 smoke. So when the ordinance speaks of No. 3 smoke or greater, that is entirely reasonable. It is so reasonable that every manufacturer with ordinary hand firing could come under No. 3 smoke. I am one of those who say this ordinance is entirely too mild. Perhaps I am radical but I have given it more study than most citizens have.

It would be a great misfortune if the news were to go out that Pittsburgh is trying to stifle the manufacturers by a drastic smoke ordinance. We are trying to make Pittsburgh a livable city, we are trying to induce smoke makers to have a little civic pride and stop the smoking which is entirely unnecessary in most cases. Since the ordinance was discontinued by the order of the Court, from my point of vantage on the 24th floor of the Farmers Bank Building I have been able to observe conditions and in the last six or seven months the smoke in Pittsburgh has increased 50 percent over what it had been for 18 months or two years previously, and the city of Pittsburgh is not a bit more prosperous today than it was twelve months ago, in fact less prosperous because we are producing less iron and steel. Since Mr. Searles has not been looking after smoke makers they have become careless. Ninety percent of the smoke made in the City of Pittsburgh is due to carelessness. So an ordinance of this kind, as mild as it is, will do Pittsburgh some good and I am hopeful that Council will in two or three years see the results and make the ordinance much more drastic. We all know what it is to light a new fire, but there is not an engineer in this room who would say it takes an hour of No. 3 smoke to light a fire under a cold boiler. Number 3 and No. 4 are what we are talking about as objectionable smoke. Any ordinary fireman can reduce objectionable smoke to within eight minutes in an hour if he will.

Mr. H. C. Porter:* We find in the laboratory that the reason some coals smoke easily and others do not, is that coals vary considerably in their chemical nature. The substances which go to make up the coal may in one case resemble cellulose in compositon, and in another they may resemble more closely a pitch or natural bitumen. On the application of heat there is chemical decomposition of these substances to produce gases and vapors of a composition and quantity varying with the coal. In some cases these decomposition products are rich and tarry, in others they are thin and watery. From Pittsburgh coal,—31 percent volatile and three percent moisture,—the gaseous pro-

*Chemist, U. S. Bureau of Mines, Testing Station, Pittsburgh.

ducts distilled from the heated coal on the grate are about 4/5 combustible, and more than one-half tarry and smoke-producing. From a Middle Western coal on the other hand, of the same volatile matter and 10 percent moisture, the products distilled are only about one-half combustible, and less than one-third smoke producing. These are results of actual experiments. It is thus easy to see why Youghiogheny coal is long flaming, and Illinois coal of only moderate flame length. Smoke abatement in Pittsburgh is a harder task, as far as the nature of the coal is concerned, than in any other American community.

The Pittsburgh type, for just these reasons, requires special devices to consume its volatile products,—space to burn out its long flame before striking water heating surfaces, auxiliary preheated air over the fuel bed, and mixing devices for the air and gases.

The author of the paper read this evening has suggested the advisability of a standard set of specifications for stoker equipment. It would seem from the above considerations as to the variation in coals, that this would be a difficult thing to bring about, unless merely the results to be obtained should be specified, and not the mechanism itself. Different coals require different furnace space, different grate angle and different draft facilities. A furnace setting and stoker which would burn a non-coking, medium flame-length Illinois coal to best advantage might easily rank third or fourth best for the coking, long-flaming Pittsburgh type.

Chemically considered, the difference between hand firing and mechanical stoking lies in the slower and more uniform distillation of gases by the latter method, this gradual heating not only permitting better mixtures with air, but also causing the production of a smaller amount of volatile matter, so that more of the fuel is burned on the grate.

Mr. C. E. Augustine:† There has been so much written on the subject which we have under consideration this evening that there is really not much one can say that will be new to engineers.

We all know that with a bituminous coal such as we have

†Assistant Engineer, U. S. Bureau of Mines, Testing Station, Pittsburgh.

in the Pittsburgh seam there is about 30 percent of volatile matter, which, when heated is driven off as tar vapor and gases.

These volatile substances driven off from the fuel bed should be maintained at a sufficiently high temperature until completely burned, or carbon will be deposited, also combustible gases will be lost up the stack. The combustion of coal is a chemical process, which requires a certain amount of time, and space, for a thorough mixing of the gases and air in order that burning may be complete.

Sufficient information is not available at present to warrant a statement as to just how much combustion chamber space is needed to burn Pittsburgh coal, and it is along these lines that the Bureau of Mines is experimenting. One of our tests seems to show that when burning coal at a good rate, and with a moderate excess of air, that the combustion process with Pittsburgh coal is not sufficiently complete at distances less than 15 feet from the back of grate in one kind of furnace used.

One essential requirement for the burning of Pittsburgh coal without objectionable smoke is that the coal be heated slowly and uniformly so that there may be a smaller amount of the heavy hydro-carbons driven off from the fuel bed.* Another requirement is that ample combustion space shall be provided for mixing and burning the lighter gases.

By whatever method coal and air are introduced into the furnace it is necessary that the combustion chamber be of sufficient size to burn the volatile matter arising from the grate.

Mr. W. E. Snyder: I do not wish to be understood as opposing this ordinance. What I have endeavored to point out in my discussion is the difficulty of bringing about changes in old boiler plants which will permanently eliminate the smoke. I know from experience that in some plants this is a practical impossibility, and any ordinance relating to the abatement of smoke should be so drawn that obedience to it is a practical possibility.

I simply want to say in addition that I have outlined to you some of our experience for the purpose of indicating the difficulties with which the manufacturer has to deal in his efforts

*U. S. Geol. Survey Bulletin No. 403, p. 47.

to operate the works and at the same time eliminate smoke. I can say further that it is our effort to eliminate smoke in all plants, regardless of where these plants are located—whether in cities having smoke ordinances or not—for the reason which I have outlined in the former discussion, that smoke is a symptom of incomplete combustion, which means a loss; also smoke is a blot on any landscape, and no manufacturer—at least most manufacturers at the present time—do not want to see their stacks vomiting clouds of smoke. They are honestly and conscientiously desirous of eliminating it completely in all plants, and inspection of the newer boiler plants will show that this intention has produced results. It is in the older plants that the difficulties lie, because the changes which are necessary to prevent it are so expensive as to be prohibitive,—in many cases being the equivalent of a new boiler plant.

I know it is possible to get a whole regiment of engineers to orate on the economical results to be obtained by eliminating smoke, and on the poetic aspect of the citizens removing this dark blot from our fair landscape. However, I have discussed the conditions as they are, and in this discussion I know that I voice the experience of a great many practical operating engineers if they could be brought here and compelled to testify. Also I feel that I have a right to talk on this matter, as I have been directly connected with the operating of large boiler installations for 15 years, the larger part of which time with the operation of between 500 and 600 boilers, consuming over a million and a quarter tons of coal annually, of all kinds and grades, and using many kinds of stokers, grates and special combustion devices. Such experience ought to give some weight to the opinions that I have given in this discussion as compared to statements which consider the matter only in an academic way, and with very superficial knowledge of the entire subject. I always hate to hear any one say that his boilers formerly smoked very badly, but after taking Paine's Celery Compound three times a day for three weeks, all smoking ceased. The fact is, there is no cure-all for smoke. The thing to do is to prevent its formation by the proper installation of boilers and furnaces.

CORRESPONDENCE

Mr. E. D. Dreyfus: It has been very pleasing to listen to Mr. Sims' paper. Its style struck me as rather unique in a literary sense, but I regret to say that it embraces so little of engineering value. While he imputes many ills to stokers other than the construction he espouses, he fails to show wherein remedial improvements have actually been introduced. It should be a simple matter to locate a few installations of a type of stoker which has been so extensively used for over 25 years and aggregating about one and one-half million horse power, in which the operation has not been entirely satisfactory in every regard. In truth the success of many designs of machinery may often be best measured by denoting the ratio of troubles

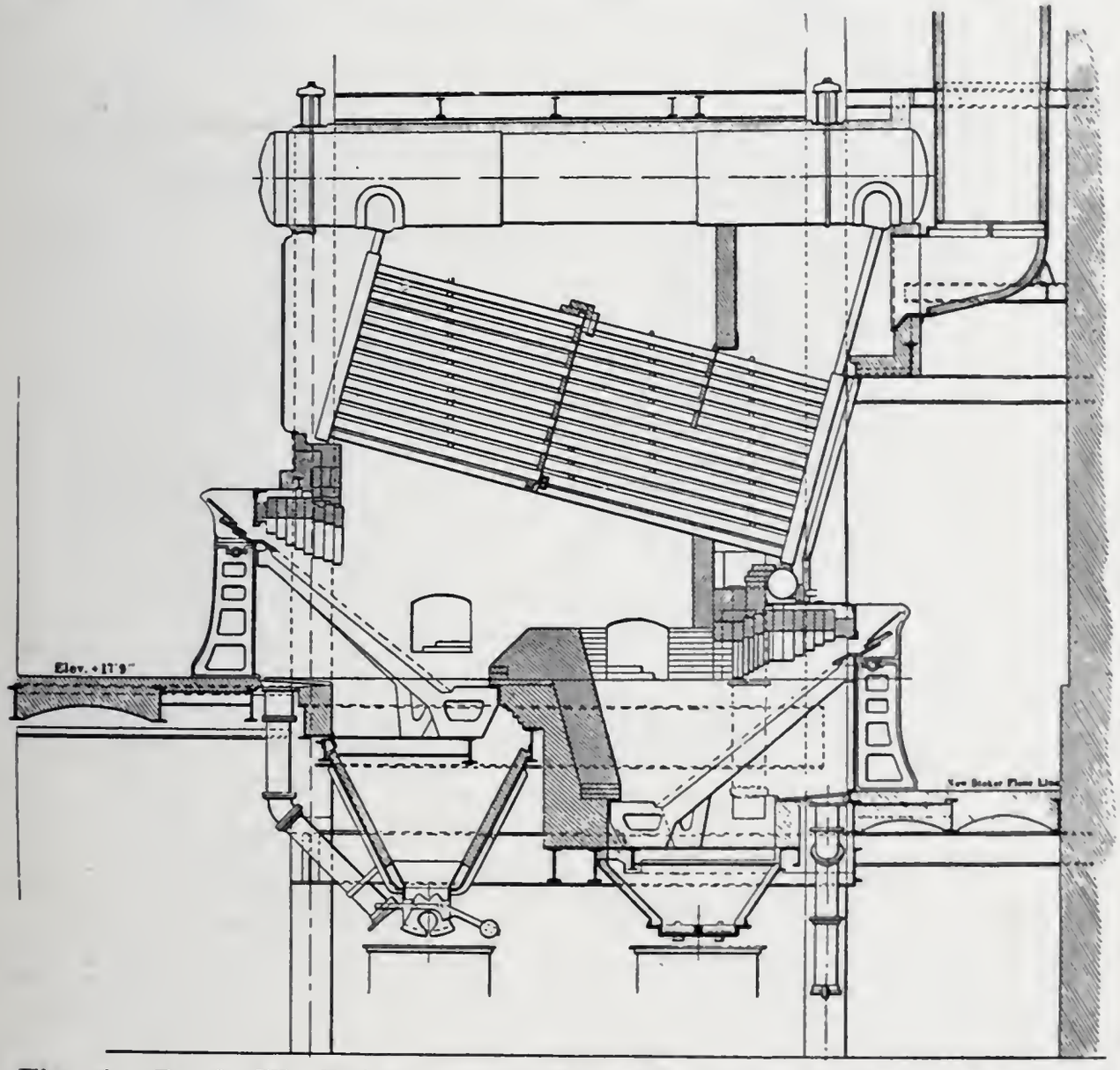

Fig. 1. B. & W. Boiler, originally with single furnace. Arranged double-end fired by H. G. Stott, Interboro Rapid Transit Co., New York City.

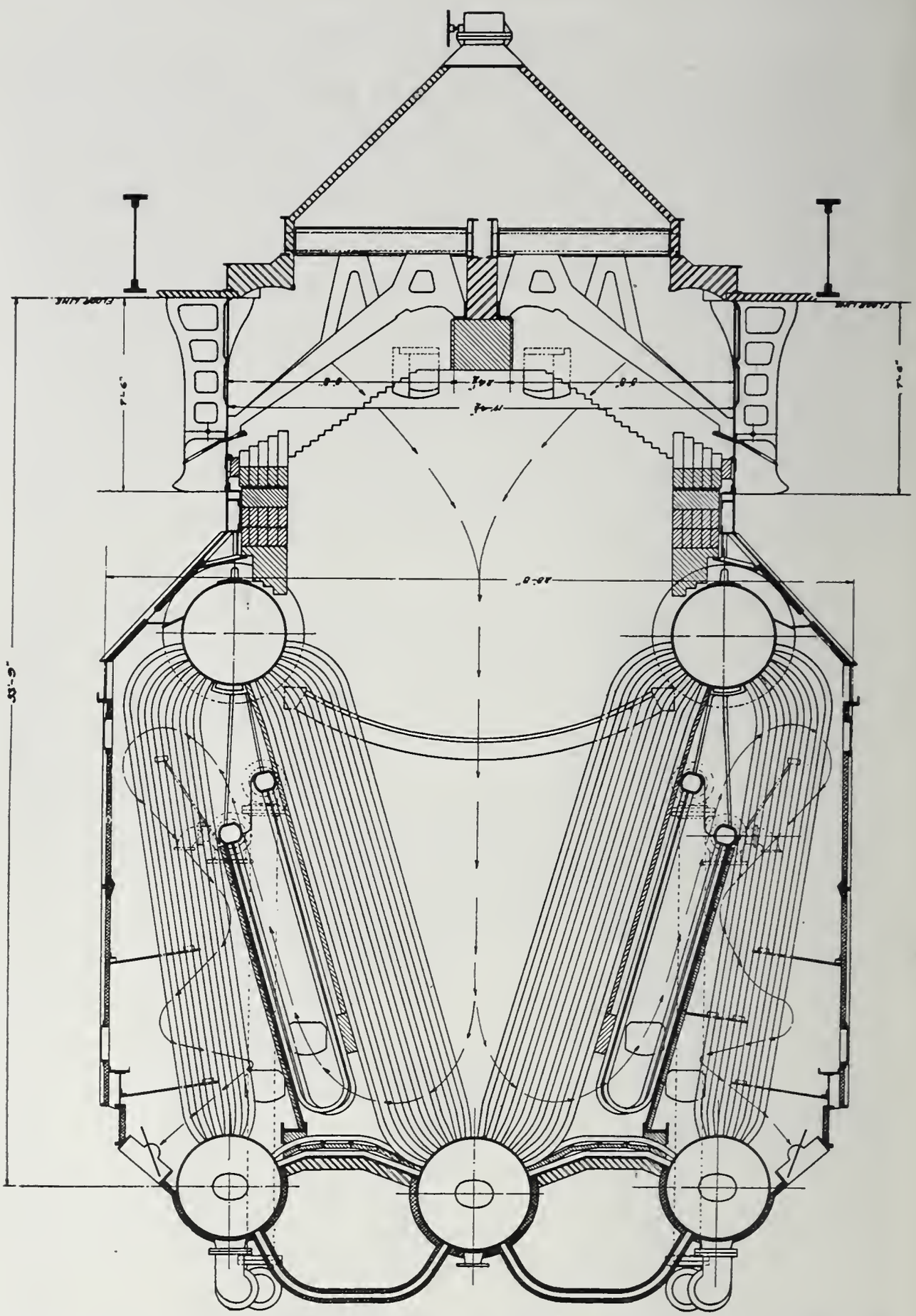

Fig. 2. 2400 h. p. Stirling Boiler with four-stoker equipment. Good combustion space provided. W. C. K. Co. for Detroit Edison Co.

to the total number of installations. So a little further investigation would have revealed another story. In point of fact, in these enlightened days of engineering, failure to make some reference to troubles encountered and cured will more than likely invite suspicion. As aforesaid, it may be possible to discover a few bad examples of a type that has been long and universally used, but this proves no case for any radical innovations, and before they may be looked upon as any kind of panacea they must withstand the test of time and hard usage.

The crux of the matter is that Mr. Sims virtually falls considerably short of the goal intended, viz., a discussion of smokeless combustion of bituminous coal. The stoker is made the distinguishing feature in the smokeless operation of a boiler plant. While it is true it is an important part, the boiler setting and furnace design are most essential factors. It would have been well to have emphasized some arrangements of furnaces conducive toward smokeless operation. To illustrate, Fig. 1, 2 and 3 are referred to as exemplifying some of the best developed layouts in modern practice. Fig. 1 is a double-end fired B. & W. boiler, 800 h. p., and Fig. 2 a Stirling boiler, arranged with 4 stokers, of 2400 h. p.—normal capacities. The intermingling of the opposing flames do much to break down the tarry compound in the coal. In Fig. 3 the latest furnace arrangement of the Commonwealth-Edison Company of Chicago is shown,—a long and high furnace having been provided. Those familiar with smoke problems will immediately recognize the advantages of these designs.* They furthermore economize in floor space and offer the solution in many instances in crowded city districts where the furnace must be reconstructed to comply with city smoke ordinances. From what precedes, the incorporating of stoker specifications in the city ordinance would in a large measure be irrelevant to smokeless combustion. It is primarily a question of rational furnace design.

Mr. Sims refers to the high efficiencies obtainable, but leaves this topic without confirmation by tests. The best results in this direction have so far been obtained with the inclined

*I am indebted to the designers of these furnaces for the privilege of reproducing them.

grate type, or what has been alluded to as the avalanche type by some discussers and tests in which efficiencies much over 80 percent were realized will shortly be made public. Moreover, this type is capable of large overload capacity and has without difficulty or undue forcing developed 225 percent rating, and is

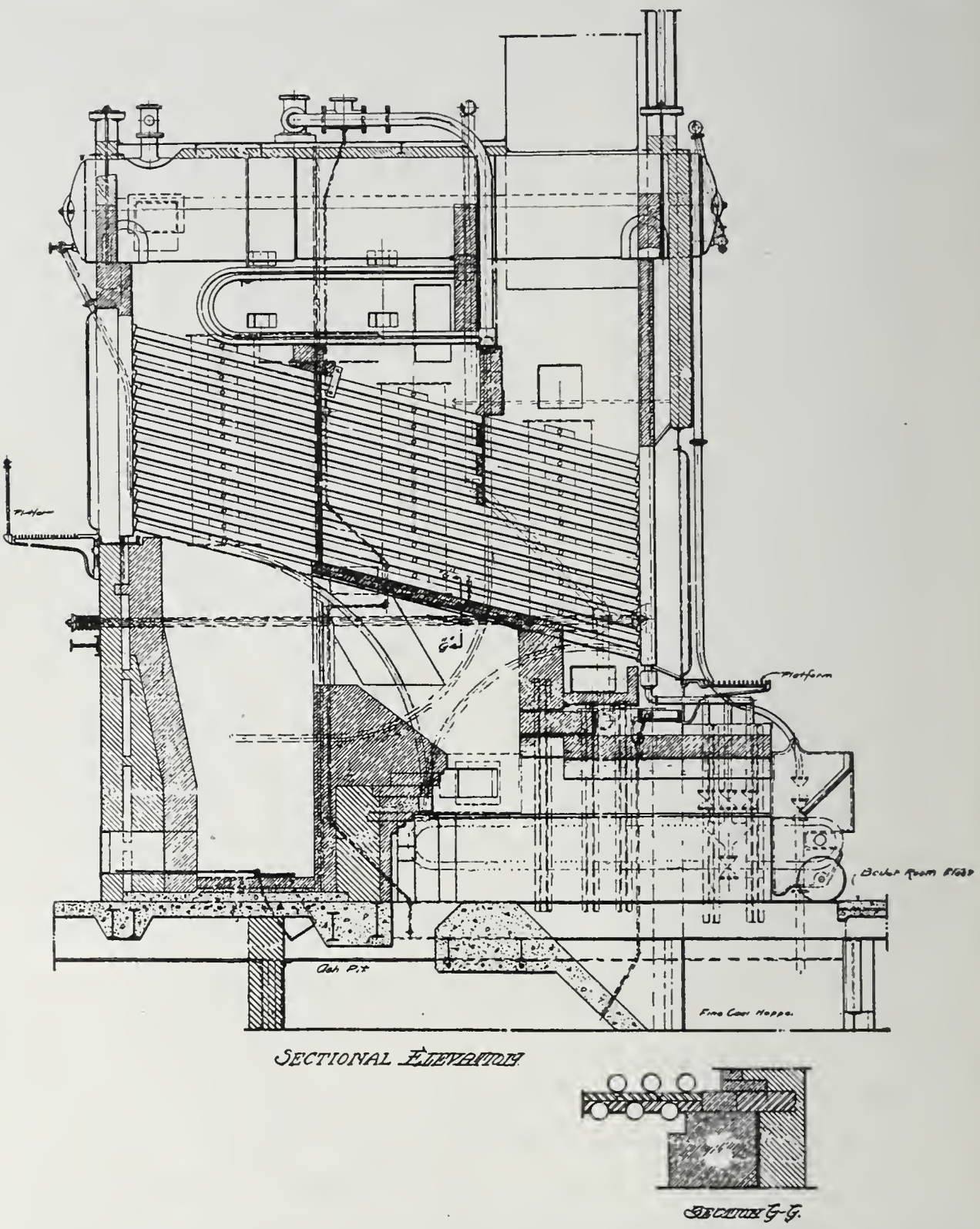

Fig. 3. B. & W. Boiler with ordinary position of furnace. Revised to secure a high and long combustion chamber; designed by F. Sargent (Sargent & Lundy) for Commonwealth-Edison Company, Chicago.

readily accessible for inspection and repairs. From its various aspects then the claims for superior results in different designs is raising hopes greatly.

The weight of discussion of the evening seems to have centered more about the abatement of the smoke nuisance from the standpoint of civic betterment than from features of stoker design to produce economic results. In connection with the municipal problems before us, and which may also concern the community at large, I have just observed a practice in chimney construction being advanced in Germany and termed "lantern" chimneys, shown in Fig. 4, devised for the purpose of preventing flue gas and smoke nuisances. Soot and particles of fine ash are not necessarily a menace to health, but the contamination of the air with vicious acid gases will prove detrimental to plant life. For example, if SO_2, HCL, HFL, etc., exist in the air even in so small an extent as one part SO_2 in 50 000 parts of air, it is sufficient to cause damage if acting constantly for protracted periods. It is reported that the volume percentage of SO_2 in the air in different cities is about as follows: Berlin .000035 percent; London .00039; Glasgow .00042 and Cleveland .0021 percent. How Pittsburgh would compare, it should not be difficult to speculate, it would at least equal that of Cleveland.

Several mechanical and chemical methods have been employed to reduce the unit density of the poisonous gases emitted from the smoke stacks, all of which have been attended with more or less indifferent success, if not in many cases flat failures. The scheme of "trellis" top chimneys here represented, appears to be one of the latest developments along this line in Germany.

It is estimated that the amount of SO_2 in the flues and stacks, is tremendous, compared with the percentages above given, even where ordinary coals of one percent volatile sulphur content is burned.

The advocates of this construction claim that in the bulk in which the gases belch forth from the regular form of stacks, the air and wind cannot dissipate these quantities at a sufficiently rapid rate to effect the diffusion necessary to reduce the concentration of the gases to a point where it will be harmless when it reaches the trees and vegetation in the immediate

vicinity. Moreover, it is contended that the gases are not very hot when they leave the stack and further still, cool off very quickly, which condition, it is argued, militates against the desired mixing of the gases with the air, especially when they are accelerated by the velocity of the wind itself. Consequently, at comparatively short distance from the stack, the dissipation takes place very slowly. To aid distribution and spreading of the gases, the accompanying "trellis" chimney designs have

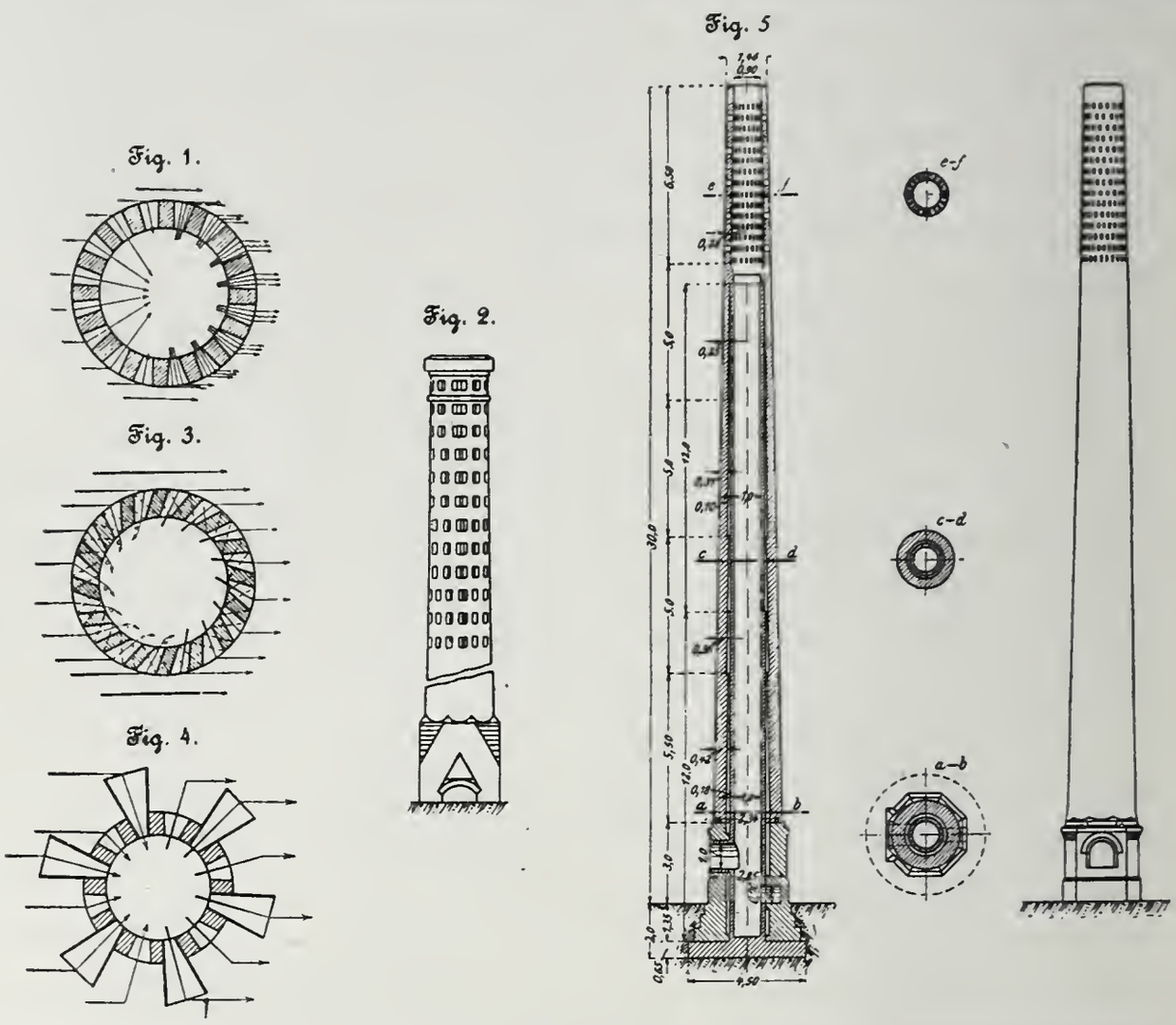

Fig. 4. Some new developments in chimney construction proposed in Germany.

been made. As to their real value, I am at present unprepared to state, but it may possibly be worthy of the attention of engineers engaged in civic activities. It would, of course, add considerably to the expense of stack construction, but would in itself, represent a very small percentage of the entire cost of the plant. Where boiler plants are located adjacent to parks or horticultural gardens, the city may have especial warrant in ruling that such features be incorporated in the chimney design.

Mr. B. F. Burman: Speaking of combustion I should like to call your attention to an expression which I consider wrong and misleading. I refer to "smokeless combustion", a term that seems to be, more and more, accepted and used whenever ideal conditions are desired in the furnace.

We are fighting the so called smoke evil, not only for the benefit of people in general in order to make life more healthy and homes more livable, but also for the property owner who is directly affected as the people suffer. At the same time, we are also fighting a battle for the benefit of the owner of the plant, although he often takes a hostile position against this "smoke prevention". It is a well known fact that a smokeless stack may, under certain conditions, evolve gases that are most poisonous to human beings; again, that same beautiful chimney which stands seemingly lifeless may belch out immense quantities of hot air, to the great loss of the owner.

Engineers have great responsibilities in this respect; the public relies upon our statements and the owner of the plant takes our advice. The former, through proper authorities, passes ordinances partly false in effect and the latter often makes improvements to his plant or buys equipments that are really ruinous.

According to law, as far as I know, there is nothing to prevent the smoke inspector recommending any kind of smoke killing device and, in this way, satisfy both the public and the owner. Think, for instance, of all these illustrious schemes flooding the combustion chamber with steam. Killing, indeed, they are both to smoke, human body, and to the owner's pocketbook. But everybody is satisfied; strange, is it not?

Here is another example: A large plant equipped with chain grates. For fear of getting into trouble with Mr. Smoke Inspector, this boiler foreman has invented something which he proudly explains to you as being superior, namely, he completes the combustion about two or three feet from the bridge wall, thus leaving a big opening and an enormous amount of cold air to get through and sweep through the entire boiler setting. The owner would certainly have a stroke if he only knew the number of thousand of dollars that this man wastes for him.

By all means, let us stop using an expression that is so misleading. Let us adopt another one more true to the cause of our fight.

Economical combustion is what we are after. We want to prevent obnoxious gases leaving the furnace and we want to save money for the owner. Smokeless combustion will come as a matter of course.

Can economical combustion be had in a furnace with a stack that is free from smoke and poisonous gases and at the same time be a money maker for the owner? In most cases, certainly. However, the only way to attain this is by means of selecting proper fuel worked by means of the right kind of stoker arrangements with the proper amount of air admitted and checked up by automatic flue gas analyses. Let us have a smoke law that compels the smoke inspector to pay some attention to flue gas analysis and not rely entirely upon the Ringlemann smoke chart. Thereafter, it would not be possible for anybody to recommend any uneconomical equipment, and the owner of the plant will be the smoke inspector's friend when he sees that his recommendations are saving money for him.

ENGINEERING REQUIREMENTS IN BITUMINOUS COAL MINING

By William E. Fohl*

With an audience of engineers I think it will not be necessary for this paper to dwell long on the importance to our community of the industry which deals with the mining of coal and its preparation for use in the other industries, either as a raw fuel or in the form of coke. But, while its importance needs no special emphasis, it is the desire of the Publication Committee that the activities of the Engineers' Society should be comprehensive and that this industry should receive its meed of attention in due season.

Pittsburgh's progress has been promoted largely by coal. The coal region of which the city is the commercial center and to which it has given its name embraces, roughly, an area of 4000 sq. mi. At some period of the world's history all of this was underlaid with the famous Pittsburgh bed of coal. The elements acting through long periods of time have denuded some of this area of coal, and man has been making frantic efforts to complete the devastation. Nevertheless, coal from this bed is still being disgorged through pit mouths within the city limits and considerable areas as yet untouched are still lying, virtually at the City's back door. Its horizon as outlined in the surrounding hills is approximately 300 feet above the level of Smithfield street; bringing it a little nearer, if it were still in place, it would be approixmately at the level of the twenty-third floor of the Oliver Building and the anemometer above us might be spinning merrily away 115 ft. above the coal. Beneath the Pittsburgh coal bed a vertical distance of about 640 ft. lies the Upper Freeport bed of coal. Thus,

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*Mining Engineer, Farmers Bank Building, Pittsburgh.

not only does coal form a large part of our environment; but, also, our city is literally founded upon it.

Our manufacturing supremacy has been largely due to the excellent coke furnished us by the Connellsville coking coal basin. Every little while we are informed that the supply of coking coal is being rapidly depleted and fears are expressed concerning the continuance of our coke supply. Such prognostications fail to take into account the large areas, of comparatively recent development, in the Lower Connellsville Region or the still larger areas practically untouched in Greene and Washington counties. Coming still nearer home, drillings and mine operations have disclosed during the past ten years a body of coal lying within ten miles of the city, with an approximate acreage of 40 000, underlaid with at least six feet of merchantable coal. It has been shown by comprehensive tests to be well adapted to coke production after the simple preparation of washing. The area stated is nearly half as large as that of the old Connellsville basin which has been producing coke in quantity for more than 30 years and will still be producing at the end of another 30 year period. Being neither a prophet nor the son of a prophet, I shall not undertake to say that Pittsburgh will not lose her proud eminence in the manufacture of steel; but this I know if that event occurs in the next hundred years, it will not be by reason of a scarcity of coking coal within the borders of the region properly tributary to her.

Enough has been said to show that we have in our immediate vicinity sufficient bituminous coal mining to furnish an epitome of engineering effort in that direction, and it would be entirely possible to show that while we have our sins of omission and commision, we are on the whole, in line with the advanced practice of the world.

The popular conception of the mining engineer is that he is the man who surveys the lands, makes maps showing how the mines should be worked, drawings showing appliances for handling the product, and directs the building of shelters for the workmen. Even this conception is found in practice to be fairly comprehensive, and when there are added a few requisites not included in it, the engineer discovers that it would be great-

ly to the advantage of the industry, if he were able to combine in one person the qualifications of the Geologist, the Civil Engineer, the Mechanical Engineer, the Structural Engineer, the Electrical Engineer, the Gas Engineer, the Architect, the Chemist the Lawyer, the Executive—in short, a composite photograph of the members of the Engineers' Society of Western Pennsylvania would give an excellent portrait of the ideal Mining Engineer.

We are fortunate in this industry to find much of our geological work already performed by the Federal Government. Its finished folios are very nearly the last word on the coal beds in a given locality, covering structure, quality, uses, and giving helpful hints for the mining, preparation and disposal of the product. The preparation of these folios for the coal bearing territory within the United States is a stupendous labor and moves very slowly. We are thankful, though, to find that the scouts of the Geological Survey have been before us in the most remote parts of the country, in some cases having gone no farther than to make a careful reconnaissance, while in others topographical sheets have been completed which give an excellent basis for preliminary exploratory work. With the wide scope of its activities the Survey is specially fitted to work out the correlation of the coal beds. At first glance it may seem of little moment that we are able to say with certainty that a coal exposure is of the same bed as another distant the width of several states, but when the identity of one coal is established, we know—not exactly what is above and what is below it, but exactly what cannot be found either above or below. Definite knowledge of this sort would have saved much fruitless prospecting in the past. We need from the geologist simply a continuance of what has been so well begun. I know of no better agency for this than the Geological Survey and I earnestly hope that the powers that be will continue the needed support, principally appropriative.

The increase of productive capacity over the demands of consumption, with its corollary of small profits, brings into prominence in this industry the factor of efficiency. This word is much in use in these latter days, nearly always with the

implication that it is calling attention to some new phase of human endeavor. This seems to me not warranted, for there were task masters in the days of the Pharaohs and I have no doubt many an Egyptian executive won commendation and promotion by his ability to secure the maximum of labor per Jewish unit with the minimum of material.

We cannot look upon the numerous applications of mechanical devices to the mining, transportation and preparation of coal in any other light than as strivings for efficiency. At the same time, we have begun to see that we have laid undue stress upon the machine and, at least partially, neglected the man. The man himself has banded together with his fellows and forced himself upon our attention with innumerable demands, all converging at the same point, more money for less labor. In sections where trades unions are most firmly intrenched, unit prices have been fixed upon every conceivable sort of mine labor, too often without any real idea of the quantity of each that a man should be called upon to perform in his working day. We cannot hope for systematic studies of these matters by the labor unions. Within their ranks there are stores of information which is not available, as their members are without necessary training to classify their knowledge and spread it abroad for the benefit of the industry.

In my judgment the executives of this industry have erred in not properly dividing the labors of mining. Too much has been required of the ordinary miner or digger. These are now largely of foreign extraction without previous training in industrial pursuits. They are being required to perform labor novel to them with no ability to even understand instructions. Under this head may be classed track laying, timbering, drilling for shooting the coal, and in some instances, the actual shooting. It is too much to expect these labors to be well or economically performed by these men. They should be set apart and carried on by men trained for them and having sufficient acquaintance with the English language to understand necessary instructions. We have no objections to these aliens seeking to share our labors in the mines; they are, in fact, indispensable. But the actual shoveling of the coal into mine

wagons is the only labor similar to that which they have been accustomed; and it seems to me that it would be to our mutual benefit, if their activities were confined to this line of work until they had acquired a working knowledge of the language, making it possible to determine whether they are or can be fitted to the other divisions of mine labor requiring more or less mechanical skill.

This is by no means a full statement of the troubles besetting the executive staff of this industry; it is merely the one which has obtruded itself upon my attention. The Executive has brought the mechanical side of the industry to a fairly high state of efficiency by using the engineer. It now remains for him to see that the human side is studied, either by the engineer or by someone else borrowing the engineer's patience, close attention to detail and habit of generalizing only upon observed facts.

Although our productive capacity is at present considerably in advance of the needs of consumption there is little doubt but that, if we were dependent solely upon the brawn and muscle of men and animals, there would be an alarming deficiency. Mechanical processes assist every step in coal mining. Very naturally, they have more nearly attained perfection in our outside plants, gradually decreasing in efficiency as the working face is approached.

While it is not of frequent occurrence, it is entirely possible to find in the same coal deposit material for all the uses to which coal is now put. Given this, our best construction engineers could now give you a plant in which coal would travel from the shaft bottom to its final consumption with merely the suggestion of human assistance. Hoisted by powerful engines, it would be dumped automatically on screens, be divided into lump coal, running by gravity into the railroad car which would carry it to the community without natural gas, there to be converted into cheerful heat in an open grate; a secondary screen would give nut coal, also running to a railroad car to be transported to gas plants and to scattered steam installations in which the fires are still fed by hand; the remainder, slack, would be divided, a small portion traveling on conveyors to the plant,

automatically fired, furnishing steam, for use at the mine itself, to run electric generators, air compressors and steam engines for various uses; the bulk of the slack would be elevated by conveyors, dropped into washers and prepared for the coke ovens where machinery would charge it, level it, and after a 48 hour interval, water it, push it, and, finally, convey it, robbed of its volatile matter, as coke to the railroad car which would carry it to the blast furnace to play its part in the manufacture of steel.

But our greatest mechanical difficulties are found at the working face. Here the mechanical engineer has attempted in vain to give us a machine to entirely replace the man, with his pick and shovel, drill and explosives. He has succeeded, however, in furnishing machines to cut the coal horizontally either at the top or bottom, or to make the vertical cut which has been designated as shearing. This partial achievement has increased the production, per man employed, nearly one-third, as shown by, comparison of the production in 1908 in Ohio producing about 75 percent of its coal by machinery and Iowa producing only one percent by the same means. It has increased production, too, by making easier the employment of unskilled labor at the face. However, it has never yet proven profitable to make more than one cut by machinery. When consumption again approaches productive capacity we will be asking the Mechanical Engineer for a machine with which we can profitably cut, to descend to slang, rings around the coal.

We have long since passed the day when every mine was a law unto itself, but our system of government is such that we still have a different statute regulating coal mining for each state in which it is carried on. This lack of uniformity has handicapped the industry in various ways, notably, in allowing cheaper production in the states with less stringent laws, and, in these same states, the development of an indifference to discipline, carried by the miners themselves from state to state. Many of these untoward conditions have been ameliorated by the work so ably begun by the Geological Survey and being carried forward so successfully by the recently established Bureau of Mines.

By far the most important thing these agencies have done

for us, and I do not remember having seen it specially emphasized, is to show us that revolutionary changes may be brought about in the coal industry with a little help from legislative enactments. This was very strikingly shown when the Federal Government announced that it was prepared to test and grade explosives. There was a hastening of manufacturers to prepare their products to be given a place in the list of Permissible Explosives. Almost as rapidly, these explosives, when listed, were generally introduced in the mines, especially in those known to be dangerous either from gas or dust, or both in combination. I believe that it would have been an impossibility to secure the passage of laws in the various states which would have made the use of these explosives obligatory in many of the mines where they are now used, solely by reason of the prestige given them by government approval.

Similarly, to have waited for laws compelling the rendering of first aid to the injured would have been a trial of patience. The inception of this great movement was the result of the efforts of certain officials of operating coal companies, who, contrary to the generally accepted idea, did not use all their spare time calculating how coal might be mined for less and sold for more. The scope of this movement has been shown us at the recent national meet at Forbes Field under the auspices of the Bureau of Mines. The whole movement shows conclusively that sentiment is still a ruling motive in business affairs as well as in personal ones.

As I have already attempted to indicate, the coal mining industry requires assistance from every branch of the engineering profession. A number of problems still remain—some of them partially answered, some of them wholly unanswered. I shall indicate, briefly, a few to which my attention has been drawn.

We would like to know from the Structural Engineer what is to be the next building material used in outside plants, especially in headframes. In the older mining regions we have seen wood gradually replaced by steel. Mines are now opened with a prospective life of 40 to 50 years. Will our steel structures be there to witness their finish? I have knowledge of one

instance where a headframe, after standing 16 or 17 years over a shaft discharging exhaust air, required a concrete covering to arrest corrosion, which had reached a stage that made it questionable whether reinforcement, also, was not necessary. We now have storage bins of reinforced concrete. Will the use of this material be extended?

We would like to know what the Electrical Engineer is accomplishing in the matter of insulating wires to be carried through our mines. We are satisfied that trolley and feed wires carried on our haulways, if in intake air currents, require no protection, except where men and animals cross; and we are satisfied that he has given us an enclosed non-sparking coal cutter. But in the event of a fall of roof carrying with it the wires leading to the coal cutter, what is the nature of our security against short circuiting, with its attendant dangers of firing explosive gas or dust?

In the deposition of our coal beds there is in places lean coal of varying degrees of purity, but frequently not merchantable along with the other portions of the bed. Tests have shown that through the medium of the gas producer many of these lean coals yield effective heat units in excess of our best coals used under the steam boiler. In the manufacture of coke in bee-hive ovens a part of the product consisting of ashes intermingled with small pieces of coke and unburned coal, known as breeze, has heretofore been wasted. Recently appliances have been fitted to steam boilers for burning this and many plants are now operated with no other fuel, at a very considerable saving. The amount of saving may be estimated from the statistics of the department of mines, showing that over the entire coke region almost exactly two percent of the coal hoisted is used at the mines for the production of power. In some localities the lean coals before mentioned are being fired under boilers with similar appliances. We want to know from the Gas Engineer whether he is ready to give us gas producers and gas engines for all the power required in our outside plants, without the help of the steam boiler.

In common with the public at large we would like to know from the Architect, in view of the scarcity and high price of

lumber, what is to be the best available material for the building of our houses.

Is the Chemist yet prepared to tell us why some coals make a satisfactory metallurgical coke, and why others, of apparently the same chemical composition, do not?

DISCUSSION

Mr. F. Z. Schellenberg:* For the geologist, as requested, I confirm Mr. Fohl's illustration of this Oliver Building representing the place in space of our local column in the carboniferous strata, including from the Pittsburgh coal seam at top to the Crinoidal limestone at foot of the building. I would remark that the intermediate layers are fresh water deposits, the first after the marine life period ended with the animal plants the fossil remains of which are the stone lily stems we call crinoids, and I point out that the coal seams coming in 300 ft. lower, and embraced in the 300 foot vertical belt still lower, give black streaks while the Pittsburgh seam above gives a red streak on rubbing lumps together. This difference in color of streak is coincident with the salt water origin of the lower sedimentary rocks as against the fresh water rocks above near the Pittsburgh coal seam.

Some fifty years ago the salt industry flourished along these river valleys. It was obtained from brine in sands at the bottom of the Carboniferous, 1200 ft. below the Pittsburgh coal horizon, and the wells bored for pumping the water to be evaporated, gave premonitions of gas and oil occurrence in quantity, to be later developed by boring still lower to the magazines held in open grained rocks and sealed under tight cover. But this newer development had to have less regard for the shallow reach in river valleys than to the basin wave formation of the ancient, solid ground that governs all underground openings including coal mining.

Here at the northern margin of the Pittsburgh coal bed, from the higher cover extending thence continuously southward, we have the lower series of coals under the river that soon emerge, however, with the rise of all the parallel rock

*Mining Engineer, Pittsburgh.

measures N. E. and the fall of the river N. W. to outcrop at the surface.

While the lower coals, coming in 600 ft. below the Pittsburgh and contained in the 300 ft. thence down, reach out beyond this prolifically thick territory into districts where they are more easily minable for themselves. The regularity of occurrence for the whole thousand feet above and below the Pittsburgh coal of this neighborhood, does not extend indefinitely, according to borings at the southeast which give negative results.

I believe it to be now better understood than when the maps were made, that the Pittsburgh coal seam is confined to areas drained by the Ohio River, and not there throughout under thick cover. It is remarkable that up to this time the mining of any one seam only, has been dependable in any hypothetical coal group section of the strata; principally, perhaps, because any second seam near is less persistent of uniform occurrence.

In the coke region where a remnant property was to be operated, the alternative suggestion was natural that water be bored for rather than piped a long distance and lifted. Further, for quenching coke in ovens, deep mineral water is not inimical to the quality of the coke, for salt should aid in eliminating sulphur in the hot vapor conditions that exist. But the expert hydraulician had his method based on assured precedent, rather than on the experimenting technologist.

Mr. W. W. Macfarren:* In the absence of the gentleman who was slated to answer Mr. Fohl's question, "What can the Mechanical Engineer do to advance bituminous coal mining practice?" I would like to make a few remarks.

Probably two of the most needed things in this art are the elimination of explosives and a rapid method of driving entries. These things the Mechanical Engineer will surely bring to pass, and in a comparatively short time.

The writer has had the good fortune to be associated for some years past with one of the most progressive and able coal operators in this district in the design and development of a line

*Mechanical Engineer, Stevenson Building, Pittsburgh.

of machines for the "all mechanical" mining of coal. By this I mean machines which cut and load the coal without manual assistance or explosives.

We have built several experimental machines at a cost of many thousands of dollars and while these machines are none of them as yet sufficiently perfected to be called "commercial" yet none of them have shown operating faults which cannot be readily corrected. Our constructions so far have been on the line of entry driving machines; but we have applied for numerous patents on cutting and loading machines for room work; also for long wall work.

Based on my actual experience I can say confidently that it is at this time practicable, where expense is not too closely considered, to design, build and operate a machine which will move forward continuously, running and loading the coal behind it, and cutting an entry say 6 by 10 feet. Probably such machines will be produced in the next ten years which will drive an entry at upwards of one hundred feet per shift of eight hours.

It is much easier to design an entry machine of this type for a thick seam than for a thin one. All the machines which we have built have been designed to produce lump coal and I have seen lump coal loaded out by one of our machines 12 by 18 by 24 in.

We also have in mind a type of machine which would produce lump in three feet cubes if desired. It is possible to obtain from 50 to 75 percent lump with proper design. It is comparatively easy to build a machine to produce slack only. Two such machines have been built by one of the large coke companies.

Entry driving machines have been suggested for many years and have been used to a slight extent in England for a considerable time. In theory they operate with ease. But the practical difficulties are enormous. One is the smallness of the available space. Another is the comparatively large amount of power to be handled. Another is to make a machine strong and rigid enough to stand the vibration or impact. More difficulty still is the necessity for clearance for ajdust-

ment and renewals, the control of the feed to the work, the transportation of the machine from place to place, and the requirements of more or less flexibility as to changes in line, level and the height of cuts.

I know of probably a dozen plans on which a practical entry machine may be constructed each having essentially different mechanism throughout. All of these are patented. The cost of developing such a machine is great and it should not be attempted without a long pocketbook assisted by experienced mechanical talent. But the reward is great and the result is to my mind certain. After what has already been done only comparatively slight difficulties are now in the way.

The use of such machines will eliminate powder from entry work and machines of similar character will probably be developed for room work. In a sense the room machine which has to be easily transportable is more difficult to design than the entry machine.

A second apparatus for eliminating powder is the so called Hydraulic Cartridge. This consists of a cylinder having a number of small plungers extending from one side like the feet of a caterpillar. The device is placed in six inch diameter by six foot hole and the plungers operated by a hydraulic pump to break down the coal by slow, steady pressure. The arrangement is effective but has many operating faults which make its use much more expensive than powder. One of the leading operators has recently concluded a series of very expensive experiments with this device, hoping to adapt it to his mines, but was compelled to abandon it. I think from observation of this apparatus and some considerable study of it that present difficulties will be eventually overcome and that at a not distant day a practical and efficient device of this character will be obtainable. It should be adopted by every gaseous mine.

If mine owners generally would co-operate with these striving, often with limited capital, to perfect apparatus for cheapening and making more safe the production of coal, using proper discrimination of course, the advance along these lines would be much more rapid.

If incidentally I may say that the perfection of machinery for carrying out the underground operations in coal mining will offer a practically complete solution of the labor problem.

Mr. W. G. Wilkins:* I want to add a few historical facts. Twenty-five years ago in the Connellsville region there was not a single feed water heater in the boiler houses. I do not think you will find a boiler house there today that does not have feed water heaters. I do not think a single mine up there at that time had a duplex pump, let alone a compound; they were all single acting pumps.

I am not so positive on the question of boilers, but I do not think that twenty-five years ago there was a single water tube boiler in a boiler plant in the Connellsville region. I know there were many two-flue boilers, and plain cylinder boilers without any tubes. There was not a single plant in that region that made any attempt to utilize the "breeze" that was wasted, or that attempted to use the waste gases for steam-making purposes. All those things have come within the last twenty-five years.

Mr. C. B. Albree: I am connected with a firm which has been experimenting along this line, and we have designed a machine with which we have been able to load two and a half to three tons every ten minutes, and keep it up for hours at a time. This is an experimental machine, and like all other machines of that character, is not far enough along to be considered a commercial success. At the same time, the indications are that in the near future it will be successful. I think we are perfectly right in saying that within a year or a year and a half the work will be done by machines designed by engineers.

Mr. L. P. Blum: I would like to ask Mr. Albree whether he means by all entry work, all thicknesses of coal? Would such a machine cut entries in a coal bed having a uniform thickness of 3½ or 4 feet?

Mr. C. B. Albree: No mechanical device that I ever knew of will cut all averages of work. Where the bed averages six to seven feet think, it will do the work.

*Civil Engineer, W. G. Wilkins & Co., Westinghouse Bldg., Pittsburgh.

Mr. W. W. Macfarren: I would like to add a word or so. It is far easier to design a machine for entry driving in a thick seam. It is twice as hard to make a machine that will cut a three and a half foot seam as it is to make one that will cut a six foot seam. It is not exactly true, as has been stated, that a machine has not been produced that will cut lump coal. As a matter of fact, I have designed and operated for some little time a machine which will cut lump coal. I have seen lumps come out of the converter of the machine twelve and eighteen by twenty-four inches. This machine was an experimental machine and was not operated any longer than to get certain data. The working conditions weren't standardized enough to know just what percentage of slack and nut would come from the machine, but it is entirely possible, in my opinion, to design a machine for entry driving, which will produce as much lump coal as is now produced by the present method of entry driving, and probably considerably more. The machine drives a square entry. The original English entry driving machine is a round machine. One point I wash to bring out is that there are a good many ways to improve this problem.

Mr. W. A. Weldin: From recent experience, I may say that a machine will probably be available in a very short time, which will not only drive complete rectangular headings as fast as 15 feet per eight hour shift, but will also load a large proportion of lump coal. However, such a machine producing only fine coal would be highly desirable even for a commercial mine, on account of the speed with which new working places can be opened up. This is a particularly valuable feature in opening new mines. The successful application of such a machine to mining will have an important bearing on the question of whether to work "advancing" or "retreating.".

Mr. H. J. Lewis:* The first operations in the Pittsburgh coal field were drift mines and shallow slopes which afforded an opportunity for cheap development of a small acreage. As these coals were exhausted it was necessary to follow the dip with shaft mines. The expense of a shaft and its attendant

*Consulting Engineer, 336 Fourth Ave., Pittsburgh.

plant is so great that a larger area must be developed for a single opening than in the case of a drift or slope. This implies a longer life for the shaft mine and at once raises the uestion of a more permanent outside plant.

For the head frame and tipple structure, steel has been used with considerable success when the members have been made of uniformly thick material and kept well painted. Some designers have used light members and thin sections making a flimsy structure subject to destructive vibrations in the severe service and without allowance for local corrosion. These structures are responsible for much of the criticism of steel as a material for mine plants. A head frame over a shaft used as an outlet for moisture laden air carrying sulphur gasses is a difficult problem in steel, and heavy material with vigilant inspection, cleaning and painting is the best that can be offered. One of my head frames has been partly enclosed in concrete but this is rather a make shift as the original steel structure was not an ideal reinforcement for the concrete. The concrete walls though pierced with openings when possible, still forms a fairly good chimney to carry the air from the shaft on up to the steel which could not be covered. It is probable, however, that reinforced concrete may be used with success when the design is deliberately made.

For storage bins on a small base and with considerable depth, steel frames and reinforced concrete linings have been used with fair success for dry coal. For wet coal and washed coal, a shallow pile on a large base supported by a heavy reinforced concrete structure has been successfully used.

For power houses the best ultimate economy is probably along the line of concrete foundations and floors, brick walls, steel roof trusses, and heavy wood purlins and sheeting covered with slate. For more elaborate construction, a reinforced concrete roof slab on close spaced steel trusses and water proofed with pitch, burlap and gravel, or slag top may be used. Steel purlins supporting tile or concrete slabs have also been used.

The perfect design for a mine plant to last forty or fifty years with a minimum of first cost and maintenance is still an

open problem, but a good deal of progress has been made in the last twenty years.

Mr. Geo. R. Wood:* Mr. Fohl asks the Electrical Engineer what protection is possible against falls of rock on machine cables in gaseous rooms. Strictly speaking, there is no complete protection, as any armor or conduit strong enough to stand a rock fall would be too heavy for use with any portable machine. It is, however, possible to locate a fuse or small circuit breaker in the machine line on the heading, where the air is free from gas in dangerous quantities, which will, in general be adequate protection. In any case, a short circuit on the cable will be on the floor of the room, and only under extreme conditions would gas be found there. This also applies to sparks or shorts at the machine. The chief proof or advantage of the gas proof mining machine is for protection against a sudden outrush of gas, such as striking a blower along a clay vein. This blower might be, and has been ignited by a sparking commutator. It is unlawful to attempt to operate even a closed machine where gas can be detected by a safety lamp, say two percent, so that with the machine on the floor and a safety test at the roof, you have a good margin of safety.

I might say in addition that insulated wires in a wet mine are treacherous. It should be understood that such wires are dangerous and they should be so marked, the same as bare wires. The Bureau of Mines at the Arsenal has been experimenting for the past ten months with various insulations, including rubber and the new varnished cloth. The insulation resistance of the rubber covered cable is now about 50 percent of its original value, while the varnished cloth is about two percent. A single braided covering over the insulation is completely gone in one case, and in general the ordinary weatherproof insulation is of no value whatever. One triple braid which seemed of an oily or waxy nature is still in good shape, as far as appearance goes, and would give some protection against shock. Some lead covered cable is still in first class shape. These tests will be com-

*President Wood-Randolph Company, Engineers, Oliver Bldg., Pittsburgh

pleted in a few months and the results tabulated and published by the Bureau of Mines.

There is another matter which might have been mentioned, which is somewhat off the subject. The Electrical Engineer is often called upon to determine what amount the Operator can afford to pay for electric current. This depends very largely on the amount of current used per ton of coal mined. I have lately noticed a large number of readings indicating that the average power consumption in this district is about three kilowatt hours per ton of coal mined. In this district, of course, conditions are generally favorable. The coal is hauled down hill and the water runs out. With current at three cents per kilowatt hour the power consumption cost per ton is therefore about nine cents.

The average loss in transmission in mines of this district, from power plant to the work, is certainly not less than 40 percent. This is not only a loss of power, but it means a large increase in up-keep of machinery, decreased service from the machinery and an increased cost of the labor which handles the machinery. I think it is a fair statement to say that this increased cost due to low voltage is twice the power cost.

Dr. J. A. Holmes:† What provision is being made toward the protection of the trolley line, where tools are being carried on the men's shoulders and touch the trolley line? Is there any protection from the trolley line?

Mr. Geo. R. Wood: It is almost impossible to remedy that, but the new Pennsylvania Mine Law compels the Operator to place trolley wire in a channel in the roof, or to protect the trolley wire by a trough made of boards projecting below wire at all points where men are liable to or are expected to cross under the trolley wire. Such places are also required to be lighted, so that there is every precaution taken to prevent contact with the bare wires.

Mr. W. G. Wilkins: Twenty-five or thirty years ago mining operations were on a very much smaller scale than they are today, and thirty years ago very few of the mines that were

†Director, U. S. Bureau of Mines, Washington, D. C.

laid out and opened up by engineers. One of the principals would go out and look over the ground and say, "We will open the mine here and put the engine house there, and the boiler house there." Now, the engineers are called in and everything is on paper before a stake is in the ground. That is a fair comparison between the way a mine was opened or a coke plant built in this region thirty years ago, and as it is done today.

THE AUTHOR: I would like to ask Mr. Wood what his estimate is of the cost in this district for current, for the whole equipment, for hauling, cutting and pumping.

MR. GEO. R. WOOD: This includes all the current used for all purposes. The highest records I have show a consumption of about 4½ kw. hours per ton. I have taken a number of readings and tests in Central Pennsylvania District and there it seems to run about 3 kw. hours per ton. The amount of power will, of course, vary greatly with the mining conditions. Where coal has to be hauled up hill and water has to be pumped the consumption may run very much higher than the figures given, but I should think that 4 kw. hours per ton is above the average.

MR. A. C. FIELDNER:* It has been said "that the province of chemistry is the study of the different forms of matter, their properties, and the changes which they undergo."

Bituminous-coal mining is the extraction from the earth of a certain form of matter, of varying composition and properties, solely for the purpose of producing or taking part in chemical reactions.

It follows then that a large part of the engineering requirements in bituminous-coal mining must be based on the science of chemistry. The application of chemical principles is necessary from the time the first prospect sample is sealed and sent to the laboratory for anaylsis until the last ton of coal has been converted into useful work.

A chemical survey of the different seams, or parts of coal seams, will establish their composition, and the particular purpose for which the coal is best adapted. In a bed of coking coal,

*Chemist, U. S. Bureau of Mines, Testing Station, Pittsburgh.

there may be certain portions, containing excessive amounts of sulphur or phosphorus, which are not suitable for the manufacture of metallurgical coke. Laboratory tests will determine the improvements in quality that can be produced by picking or washing. Sulphur and volatile-matter determinations will show the suitability of the coal for the manufacture of illuminating gas. Proximate analyses and calorimetric tests of the coal as shipped will protect the operator in selling his product on a B.t.u. basis.

It is only within recent years that the coal operator has called on chemistry to adjust his troubles with the dissatisfied consumer. Formerly he sent out the jolly, good-natured salesman, with a liberal expense account and a pocketful of cigars; now he sends out the chemist with an Orsat apparatus to determine how much heat is lost in the flue gas. It is the chemist's duty to show the cconsumer how to secure the maximum energy from the fuel. This is especially necessary when the fuel is being introduced into a new field. The fireman who is accustomed to burning New River coal, with 20 percent volatile matter, is not likely to secure complete combustion with his first carload of Pittsburgh coal, containing 30 percent volatile matter.

Another important field for the chemist is in the supervision and testing of supplies and materials used in mine operation. The explosives, detonators, and fuel oil for the lamps, should meet the requirements of the State mine inspector. Acid-resisting materials are desired for handling the corrosive mine waters. The most durable insulation for electric cables, when subjected to mining conditions, should be selected. The boiler water may require chemical treatment to avoid scale formation or corrosion. And in many other ways can the chemist aid in the selection of the material best adapted, from the standpoint of cost and service, to the particular conditions of mine operation.

Dr. H. C. Porter:* One of the most useful of the applications of chemistry to coal mining is the examination of mine air and gases. This subject has been especially studied by Mr.

*Chemist, U. S. Bureau of Mines, Testing Station, Pittsburgh.

G. A. Burrell of the Bureau of Mines and can be best discussed by him.

The use of calcium chloride or other hygroscopic substances for retaining moisture in mine roadways and working areas, and thus retarding dust formation, is an application of chemical principles. The exudation of inflammable occluded gas from freshly mined coal and from the freshly exposed face for a long-continued period is a fact contributed by chemical investigation of coal.

Spontaneous combustion in gob piles in the mine and in the dumps outside the mines is a chemical problem receiving much attention. Its explanation is, as yet, by no means clear, but the conclusion is fairly well established that the main cause of spontaneous heating lies in the slow oxidation of the coal itself under conditions which allow the slowly developed heat to accumulate and do not allow it to be radiated. Sulphur and other impurities are contributary but not the main causes.

As to why some coals coke, and others of nearly the same proximate composition do not,—chemists are at work on the problem and have been for many years, but it is not yet solved. The explanation of the coking quality lies probably in the chemical nature of the carbon, hydrogen and oxygen compounds present,—not in the ash or other impurities. Coking coals generally contain low oxygen percentage in ratio to hydrogen, and yield on heating a volatile matter rich in paraffin hydrocarbons. Non-coking coals break down on heating so as to yield volatile products containing large amounts of water and carbon dioxide, and lesser amounts of hydrocarbons.

Mr. G. A. Burrell:* Gas chemistry finds it greatest application in coal mining in the detection and determination of that gaseous constituent common to all coal mines, fire-damp or methane. A substance in which there lies a potential force capable upon release of wrecking the best planned devices of the mining, electrical, mechanical and civil engineer, must be, and is, given great consideration in the operation of a mine.

Coal mines are roughly classed as gaseous and non-gaseous. In the former we find safety lamps in use, electric wires cau-

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tiously laid, and a more strict supervision maintained than in the case of the so-called non-gaseous mines. That the line of demarcation is too loosely drawn is shown by the fact that in non-gaseous mines explosions have occurred which have apparently been originated by the flash of a gas pocket exciting to action the tremendous energies locked up in the coal dust. The writer has in mind a coal mine where gas had never been reported by safety-lamp indications. An explosion occurred and a score of men lost their lives. Not long afterward, when the mine had resumed normal working conditions, gas in dangerous quantities was found, according to analyses made by the writer.

The safety lamp undoubtedly is one of the greatest aids to safety in mining ever devised, but today, as part of the great effort to minimize the death rate in mining, more accurate control of the firedamp exudation is desired. Systematic analyses made throughout different parts of the mine define the potentiality of the mine toward firedamp explosion. A better distribution of the firedamp throughout the air current is made possible. It is generally the case that sufficient air is being circulated throughout the workings, but ofttimes one split carrying considerable firedamp does not have circulating through it any more air than another split carrying less methane. A readjustment is often possible.

The person who gives to the coal-mining industry a simple and efficient firedamp detector capable of detecting unfailingly 0.25 percent of methane in a mine atmosphere, or even 0.5 percent with the ease with which the ordinary safety lamp detects two or 2.5 percent, will have accomplished great good. Until that time we must have resort to gas analyses for the greater refinements. Fortunately, much greater accuracy can be obtained with some apparatus, in the use of which a determination can be made in less than 10 minutes and which are not complicated.

Anything which affects the health of the miner in the work he has to do, of course goes farther in that it affects the economics of the coal industry. I have particular reference to the condition of working faces after explosives have been fired to

break down the coal. Harmful gases are released, carbon monoxide among others, and the Bureau of Mines has been examining these products of combustion with a view to a minimum escapement of these constituents, in that the composition of some of the explosives may be altered to this end.

I have in mind other problems in the solving of which the gas chemist assists, such as the effect of small quantities of gas, below the explosion proportion, in causing the initiation of coal-dust explosions, the testing of explosives, the standardizing and use of safety lamps, the effects of broken electric light bulbs on gaseous accumulations, the use of explosion-proof electric coal cutters, intrusion of natural gas in mines, the use of gasoline locomotives in mines, effect of barometric pressure on methane, etc. An important point has to do with the length of time a properly sealed mine fire should remain sealed.

Some elaboration on these problems may be interesting.

Gas and Dust Explosions: Laboratory experiments have demonstrated that methane in quantity below the explosion proportion (about five percent methane) becomes explosive when coal dust under certain conditions is present in the atmosphere. The Bureau of Mines has not as yet made experiments of this character, although the problem is to be taken up in the near future. I quote from other sources then in saying that as little as two percent, or even less, methane becomes explosively dangerous under proper dust conditions, when with gas or dust alone an explosion would not take place. The statement certainly looks reasonable considering that dust alone under right conditions explodes. This certainly means a more rigid control of, and inspection for, firedamp in coal mines.

The Testing of Explosives: At the Pittsburgh testing station natural gas is used in preparing the gas-air mixtures for use in testing explosives. Methane (CH_4) is the combustible gas commonly found in coal mines. Unless due to natural gas intrusion, higher members of the paraffin series are seldom encouraged. The natural gas used in Pittsburgh contains approximately 83 percent methane, 16 percent ethane and one percent nitrogen. A study of the explosive properties of the natural gas showed that it behaves similarly to methane in its explosive

properties, or tests of explosives using Pittsburgh natural gas give similar results to tests using methane. Explosive and non-explosive proportions of gas and air are prepared, the latter being mixed with coal dust, and explosives are fixed into the mixtures to determine the liability of the explosive to ignite gas, or gas and dust.

Testing Safety Lamps: So dependent are most mining companies on safety lamp indications for showing the danger or immunity from fire damp explosions, that tests showing the reliability of different safety lamps are highly desirable.

A rapid thrust of a poorly bonneted lamp, which is the same thing as subjecting the lamp to an air current of high velocity may project the flame through the gauze into an explosive mixture.

The fire-boss in his early morning inspection trip determines the condition of the mine, as regards danger from fire damp and other causes, for the working force who follow. His capability of detecting gas by means of his safety lamp sometimes means the difference between the maintaining of normal conditions during the day, or a wrecked mine and lives lost because of an explosion. It is essential then that he knows the trustworthiness of his lamp under all conditions of its usage. An important point has to do with the personal equation in gas testing with a safety lamp. The fact is not fully appreciated that different observers under the same conditions of testing may arrive at different results. The question of a man's own eyesight is of prime importance. It is also true that the user of a lamp has seldom checked its sensitiveness to gas or his ability to detect gas, against the exact analyses of the mixtures examined.

Intrusion of Natural Gas into Mines: I can impress the importance of this question more forcibly upon you by reciting in brief the history of an explosion which occurred in West Virginia recently.

The particular mines affected were considered non-gaseous. The progressive company who operates them maintains strict chemical supervision over the gas in all their mines. Consequently, when explosions occured in two adjacent mines early one

morning and killed two men (the working force were just about to enter) some other cause was looked for than normal methane accumulation. It was found that a natural gas casing passing through a barrier pillar in one of the mines was responsible for the gas intrusion. It might be mentioned here that the company feels that their strict precaution as regards explosion from coal dust prevented a sweeping and disastrous explosive wave passing through all the workings. The question of natural gas intrusion is going to be given serious consideration when certain tracts of valuable coal lying deep and close to natural gas sands are worked. This formation occurs in one part of West Virginia, perhaps other places also.

Effect of Barometric Pressure on the Escape of Methane in Mines: Experimental work so far conducted shows that a relation exists between the fluctuations in atmospheric pressure and escape of methane from mines. Some mining men have protested that such cannot be the case but experimental evidence does not bear them out. Two series of experiments conducted by the bureau, each of about one month's duration, indicate that the subject deserves consideration, although the tests were not prolonged enough to draw general conclusions. The plan is under advisement of conducting a series of experiments extending over a whole year, gas analyses and barometric observations to be made daily. I might add that at some places abroad the barometer is daily watched as a warning against increased methane escapement from the coal.

Gasoline Locomotives in Mines: The use of gasoline locomotives is a recent innovation. At some places the introduction of an internal combustion engine, with gasoline tank and exhaust has been looked upon with some apprehension and the Bureau of Mines has been asked to make a series of tests regarding the desirability of using such motive power. My interest lies in the exhaust gases discharged and a series of samples have been collected under severe conditions of usage of the motor. If necessary more samples will be collected. The results will be given to those interested.

Mine Fires: A mine fire is a bad proposition. It is likely to occur however in the best regulated mines, and time and

money is expended in recovery work. Once sealed, if this has been necessary, and under control, the question resolves itself into how long the area should remain closed and air excluded before recovery work is attempted, or how long will the embers retain sufficient heat so that air readmission will again fan them into a blaze. The analyses of the atmosphere behind stoppings is valuable to have, in that the composition of same can be determined. Anaylses will show whether stoppings are tight, i. e. whether air is inleaking so that the coal or coal and wood is kept in a quiet state of combustion, awaiting only a fresh inrush of air, as when recovery work is attempted, to cause a quickening of the combustion and start things anew. Analyses show the danger from explosion, in that sufficient methane may have accumulated to form an explosive mixture, with an inrush of air. Sufficient to say that analyses help, in that a sealed mine fire reaches its consummation only in the absence of oxygen, and with air excluded embers lose their heat in much shorter time than when the air is slowly inleaking. The Bureau of Mines has a record of many mine fires, and the part gas analyses has played is shown.

Noxious Gases from Explosives: I can give a few figures having to do with the noxious gas produced by blasting explosives.

Explosives, both black powder and permissibles, produce noxious gases when used in coal mines for breaking down coal. Samples of gas taken from crevices formed when coal has been broken down contains as much as 10 or 20 percent carbon monoxide. Hydrogen sulphide is also produced in some cases. Later when the miner prepares to clean up his shot, harmful quantities of those gases may still be present. Four minutes after shots have been fired as much as 0.16 percent of carbon monoxide has been found according to analyses made by the bureau of samples taken at the face. That is, the concentrated gases had not been diluted sufficiently by air to reduce them below a dangerous percentage. More extensive experiments will be carried on in order to determine how long after a shot these harmful percentages remain.

After-Damp from Explosion: Because a disaster has never

visited a mine does not say that that particular place is immune. Many records of mine explosions bear this out, consequently those of you who are mining men are ever on the alert for any expedient which may be used in recovery work at such times. I have particular reference to something which may be used by rescue parties as a sensitive indicator toward the presence of bad air or after-damp. After-damp finds its way into all or many sections of a mine after an explosion has occurred therein, and rescue parties are overcome and sometimes death results because no means are at hand to detect the presence of that insidious enemy, carbon monoxide. Lamps have burned normally in the presence of harmful quantities of this gas, and men have been struck down without any warning. I have experimented on small animals with a view to determining their behavior in the presence of small quantities of carbon monoxide, and have concluded that canary birds carried along with a party furnish a reliable detector of carbon monoxide. I can relate one of many experiments performed by myself.

I entered an atmosphere containing 0.25 of one percent of carbon monoxide, taking with me canary birds, mice and pigeons. The birds completely collapsed in four minutes, the mice in seven minutes, and the pigeons only showed slight signs of distress in twelve minutes. At the end of 20 minutes, I experienced a slight headache only, although later became ill. This experiment along with others performed demonstrates the greater sensitiveness of canary birds to carbon monoxide than men. In other words if a rescue party enters a mine and takes small birds with them, the collapse of the birds will warn the men of their danger and give them time to retreat.

Mr. E. D. Dreyfus:* The query at to whether the Gas Engineer is ready to come forward with gas engines and producers may be affirmatively replied to, as the gas engine and producer art has been developed to a most satisfactory stage within the past few years. There remains no doubt of the ability to generate power in a dependable manner with gas engine equipments direct from practically all the coals now commercially used and, moreover, some of the more inferior grades.

*Commercial Engineer, Westinghouse Machine Company, Pittsburgh.

The gas engine has long been a success, particularly so in moderate sizes, but the problem of consuming coal in the gas plant has been mainly confined to the producer wherein trouble was early experienced in making a clean working gas free from objectionable quantities of impurities, such as tarry compounds, lamp black and particles of dust. Engine builders require that the impurity contents should not contain more than:

0.01	grains	dust	per	cubic	foot
0.15	"	sulphur	"	"	"
0.02	"	tar	"	"	"
4.00	"	*moisture	"	"	"

If the coal contained a large percentage of fusible ash, this would possibly give rise to a troublesome clinker formation. While the demand of the Producer Engineer has been rigid, interesting solutions have been found after many years experimenting, from which has evolved apparatus manufacturing a good clean and fairly uniform quality of gas. The use of anthracite coal offers the simplest problem on account of the low volatile content. Bituminous fuel requires a somewhat different treatment, and several types of producers have been developed for gasifying these genera of coal. These may be classified as follows:

1. Up draft producers using centrifugal extractor to remove the volatile oils and compounds.

2. Double gas generator, working each bed alternately and reversing the flow of gas so as to cause the volatiles to pass through a hot bed of coke and become chemically converted into a permanent gas.

3. Double zone producers with two fire beds superposed, a simple arrangement for reduction of the tars and oily vapors.

One hardly need entertain at this time, as already observed, any feeling of uncertainty regarding the reliability of gas power. There are too many examples of excellent service today that should dissipate any prejudice which may have followed some of the disappointments met with in the development stage of the gas engine. Truly, numerous troubles had to be borne in perfecting the details of construction of this type of machinery, and it is unnecessary to remark that similar experiments have

*Above the point of saturation.

prevailed in most every line of engineering endeavor, some worse than others. The gas engine, however, does require on account of the magnitude of the forces dealt with, careful designing backed by wide experience in order to guarantee the "standing-up" qualities of the engine. The writer gave this subject more extended consideration in a paper before the Pittsburgh Railway Club about a year ago, and will only mention the question at this meeting.

While it has been intimated to you that gas power machinery now evidences the fact that it has improved to an entirely satisfactory stage from a mechanical stand point, it does not necessarily follow that it should become the most commercially economical, notwithstanding the fact that it is known to be the most efficient in the consumption of fuel.

The design of the elements of the gas power plant are inherently so different from those of steam power that they invariably become far more expensive in construction. Consequently the engineer must strike a balance between the saving in fuel on one hand and the increased investment charges on the other as compared with steam power apparatus.

The question resolves itself into three principal considerations; 1st: Cost of fuel delivered at the plant; 2nd: The character of the load; and 3rd: The loading factor. There are too many variables entering the determination of the fields of greatest usefulness of gas power to permit of general statements. A comprehensive study has been of the comparative value of gas and steam plants under different conditions, and a family of curves showing the conclusion reached are given in Fig. 1. This is taken from a paper read before the Association of Iron and Steel Electric Engineers on the subject "The Economic Relation of Prime Movers", and a more exhaustive treatment will be found in their proceedings.

At the mine, where fuel is low in cost, it may prove difficult to justify the installation of gas power unless it should be in comparatively small sizes. There is the supply of water also to be taken into account, and if the plant is to be handicapped by a contaminated or otherwise bad water, it will have a tend-

ency to work in favor of gas power even should cooling towers be used. Although the gas engine plant consumes more water than the non-condensing steam plant, much less is needed than where the engine or turbine is run condensing, their respective ratios being about 1, 3 and 20, depending upon the temperatures, vacuum, etc.

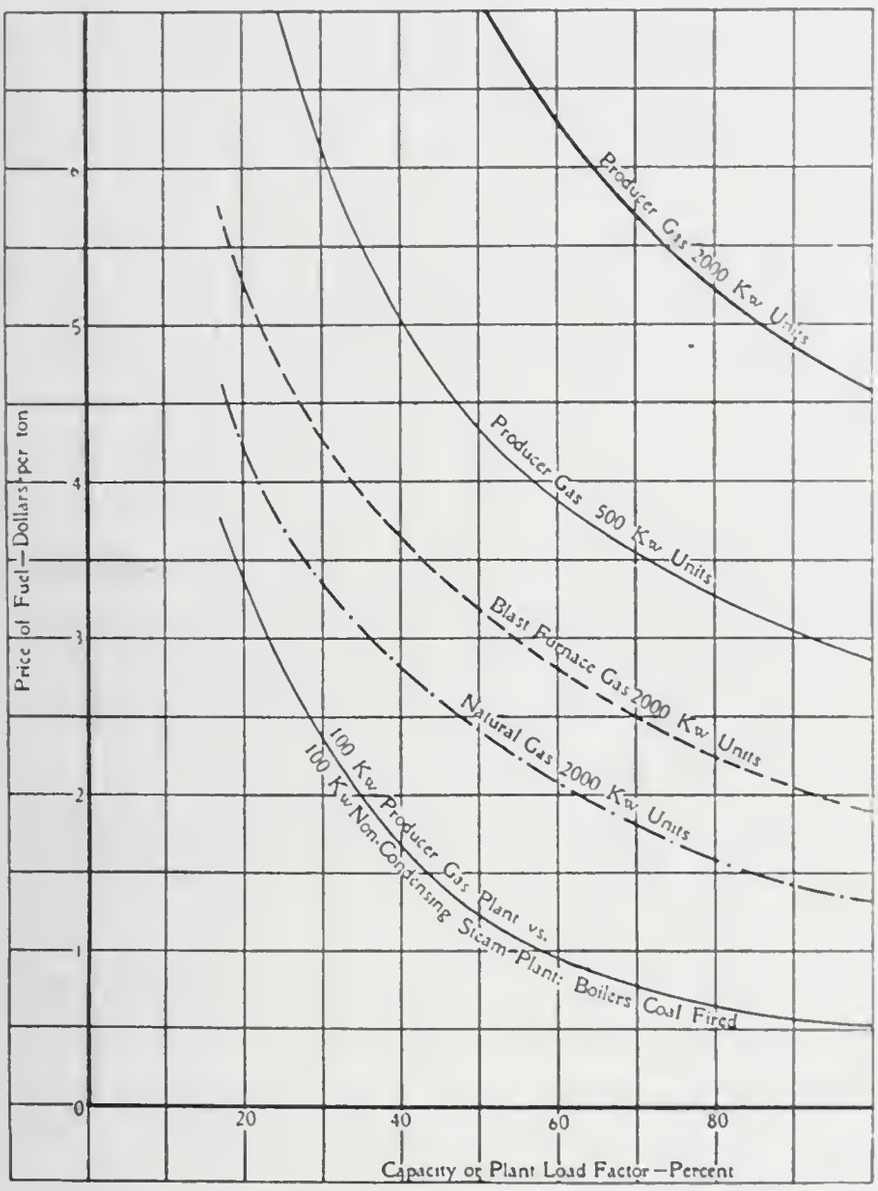

Fig. 1. Proportionate Equality Curves

Showing balance of total costs of generation in gas and steam plants with variable fuel prices and load factors.

Should the mining company operate modern shops for the repair of their equipments, producer gas for heating work may prove profitable for annealing, tempering, etc. Considerable use of producer gas in this direction is now being made.

Such factors as referred to must all be reckoned with to make certain that the equipment should provide the best investment from all points of view.

Dr. Joseph A. Holmes:† Gentlemen, referring to the question of "Legislation", I want to call your attention briefly to just a few of the features which should be talked of when the legislatures are not in session, so that when they are in session we may see the benefits of seed already sown. The history of the past indicates that it is not the drastic or stringent legislation but the results of scientific investigations that make for industrial progress. I think it is true that the people who operate mines are just as human as the men who preach in the pulpit, practice at the bar,, or who write. Laws on the statute books which are neither enforced nor enforceable are worse than no laws at all. In order to have laws enforceable they must be in accordance with economic conditions. Lately there has been a great deal of talk concerning the Sherman Anti-Trust Act. I have no doubt the Sherman Anti-Trust Act is a very good law to do the things it is intended for, but we all know that it is absolutely ruinous in connection with the soft coal business. Laws that forbid coal operators to get together on some reasonable basis are laws that make for cut-throat competition, which is ruinous to the industry, ruinous to the investor, and ruinous so far as life-saving is concerned. There is another thing we ought to bear in mind, and that is, there ought to be uniformity in mining legislation. A law which the State of Pennsylvania has enacted may not be enacted by West Virginia because it would put West Virginia at a disadvantage, and that is what we have to contend with in getting proper legislation for the prevention of mine accidents in the various states. One state is willing to do a thing and another state is not willing to do it, and then the first state is unwilling to do it. In connection with a form of government such as our own, the National government has nothing to do with the inspection or supervision of mines in the several states, and therefore it is impossible to have adopted any uniform legislation, and it is difficult to see how we are going to get it.

One thing the Bureau of Mines is trying to do is to gather and tabulate as far as possible the laws and mining regulations in all the mining countries, and bring together the court decis-

†Director, U. S. Bureau of Mines, Washington, D. C.

ions relative to these, so that they will be accessible to mine attorneys and mine operators.

One word in conclusion, concerning the relation of the investigations of the Bureau of Mines to the work of private engineers. I know it was feared some years ago that the Government work was going to interfere with the work of private firms. So far, instead of interfering, it has helped to increase the work done by private concerns, and so far as the present administration of this work is concerned, that will be our aim in the future.

Mr. S. A. Taylor:* The old adage that "Poets are born not made" might with almost equal truthfulness be applied to executives, and yet perhaps in the reading of the great works of Milton, Dante, Chaucer and others who have produced masterpieces, the impression made on the mind is of labored language and carefully worked out plan in their work, rather than the easy fluent diction of a Poe. In like manner while the person who may possess a natural executive mind and disposition may have another somewhat handicapped who has studied out and put into practice the theories of executive administration. Yet it is by no means discouraging to one who has the patience to study and apply the theories which underly the science of management, for the reason that some of the best executive officers are those who have determined upon a certain line of investigation which they apply to each question which is presented to them for solution, and their decisions, while sometimes a little delayed are usually along the right lines.

The question naturally arises what are the functions and requisites of an Executive? The function of an Executive of a coal company is the deciding of all important matters in connection with securing the best men, and employing the most advanced and up to date methods for the economical production of the coal at the mines; the determination of how much coal shall be produced, and how much can be disposed of in the market, how it shall be marketed so as to bring the largest returns to the company at the lowest possible cost. These two

*Civil and Mining Engineer, Lewis Block, Pittsburgh.

main problems present such an indefinite number of problems to the executive, that he must be equipped with the following: to-wit a good general knowledge of the business, which shall include enough of engineering knowledge to enable him to judge of the engineering necessities, including civil, mining, mechanical, electrical, gas and chemical, all of which enter into the make up of his plant.

He should be a good organizer so that he can place his men and materials in such a way as to secure the maximum of service from them.

He should possess a good knowledge of transportation for next in importance to having a good organization of men, and a good development of the coal mine, is the question of transporting and handling the coal from the working face to the railroad car—if the operation is on a railroad—or to barge and coal boat if the operation is by river. In fact when the output of a mine is large, the transportation is one of the most important items in the cost of producing coal, as it is easy enough to produce coal at the working places but the hauling requires very carefully worked out plans and a higher order of executive and planning ability than do many of the other steps in the production, preparation and handling the coal to the market.

The Executive must be a good judge of men, and in order to successfully handle them, and overcome many of their whims and fancies as well also their unreasonable demands, it is of very great importance that the Executive be a student of sociology whether he recognizes it by that name or not. He must mentally put himself in the place of the men to ascertain just what they are thinking about, and why they are so thinking, then he will be able to remedy what should be changed in the practice at the mines, or persuade the men, as to where they are in error. He must think of the home life of his employees, and if it possible for him to better their condition and make them more contented, he will have made great progress in solving or rather in keeping down the discontent which is usually in evidence in and around coal mines.

The Executive should also become as closely associated with his men as possible in order to secure their good will and

confidence and act so that his men may be brought to a realization of the fact that he is interested in their welfare. There are so many ways that this can be done, it would take too long for such a paper as this to enumerate them, but in brief would say that a good Executive will have control of his men, unless there be some extraneous power such as a labor union which will prevent his attaining this end.

Another prime requisite of an Executive is to be able to decide quickly the many propositions which are placed before him and in some cases he may have to decide without being absolutely sure he is right for the moral effect it may have. In short he must have good judgment as to policy as well as the best thing to do in any matters coming up to him for his decision.

The Executive should always see that his company maintains their credit unimpaired so that when the purchasing agent or the men at the mine need something in a hurry, or in an emergency, that it is not held up until credit rating can be gotten or security given for the purchase. This is of more value around a mine than is often accredited to it, for the feeling of anxiety lest they might lose their wages, etc., will often change otherwise careful, painstaking, and highly efficient employees into careless and inefficient ones. In this matter of purchase as well as a number of other matters as little red tape, as it is commonly called, as can possibly be gotten along with, is the best system to follow, for oftentimes if there is much delay in securing supplies or something that might be very necessary or desirable the effect will be that the men at the mine will either go along without asking for it, or if they do ask for it, it is not secured in time to take full advantage of the end to be attained by the material as planned when it was asked for.

This same simplicity will mark the ingenuity of the great Executive in office work as well as the general work around the mines as it is very much easier to have the men, such as are employed around the mine, do things which they can understand, than those things which they are taught to do without thoroughly understanding why they are done.

The Executive should have brief, daily reports from the

various departments each morning, so that he can intelligently see where the weak places in his organization exist, and then he can very clearly apply the remedy.

He should also have a general knowledge of Law, and the reading of some abridged edition of Blackstone will enable him to understand what his attorney is talking about, when he calls him into consultation, beside giving him a better view of mining law and other laws which apply directly to the coal business.

In closing would say that the Executive must have all the knowledge he can secure or master in connection with the business and must be planning ahead, so that at no time will the efficiency of his organization be impaired, and also that matters and conditions may be so shaped that the things which may at sometime give him trouble be overcome or sidetracked. If he will do this properly, it will nearly always bring to him and his company success.

Mr. Morris Knowles:* The author has mentioned several of the measures undertaken to insure safety in the mining industry and to spare the miner and his family from the great loss that has frequently occurred in the past from terrible accidents. He also states that the executive having now brought the mechanical industry to a fairly high state of efficiency, it remains for him to see that the human side is studied. It is this latter question to which I am glad to address a few remarks. In the promotion of efficiency, the conservation of human life is one of the most important questions, not only from the standpoint of mechanical and physical safety, which has been developed by the excellent work of mine inspection and supervision, the use of permissible explosives and organization of corps for first aid, etc., but there is another factor which has not as yet engaged such universal attention and which it is high time that we should think about. I refer to the question of sanitary and welfare measures, to promote the health of the miner and his family.

For a long time the building and equipment of the mining settlement and the facilities provided have been of a careless character in so far as the living conditions, conveniences of the

*Civil and Sanitary Engineer, Oliver Bldg., Pittsburgh.

employees and families and the question of water supply and disposal of wastes has been concerned, not to speak of the fact that the broader problem of social and entertainment factors have rarely if ever been considered in a fundamental way. It is easy to believe that conveniences will probably be used for the very opposite purpose of their intent, i. e.: that cellars will be used for stabling cattle and keeping pigs, and bath tubs for storing coal and refuse and because of the nature of the employees no care whatever will be given such accommodations. It may be that the temporary character of such camps, due to the short life of many of the mines, has contributed to this in the past, but it is even more apparent that gross carelessness, with a feeling that the foreigners will not appreciate and understand, has led to this lack of care for the other fellow.

How many places can be pointed out where a convenient, pure and adequate water supply is furnished directly to the employee's home, and sanitary provisions for the disposal of wastes installed? You may know of a few, but probably they can be counted upon the fingers of one hand. How many mines do you know of, in which there is any provision for a pure water supply while men are at work, or provision for disposal of human excrement within the mine, without contaminating both rooms and entry ways? All of these things are not as they should be and the frequent epidemics of typhoid fever, diarrhoeal diseases and even malaria have been most prevalent. There is no wish to convey the impression that all companies or all mines have been so carelessly maintained, for there have been some notable exceptions, in which not only the hospitals for physical safety are most carefully provided, but social and sanitary conditions are also looked after, but these examples are few compared with the many in which no such understanding is evident and no attention paid to this important subject.

Recently, with a better understanding of the cause of infectious diseases, much attention has been paid in the gathering together of numbers of men in temporary army camps and in the construction camps of many public works, notably those for water supply. Adequate and proper attention has been paid to pure water supply, sanitary disposal of wastes, with the

resultant effect that the illness has been less and the efficiency of the workmen has been greater.

Outside of the work upon the Panama Canal, one of the first of the large and important public endeavors to so care and arrange for the protection of the public health during construction was the City of Pittsburgh, in the building of the filtration works. In the contract for this work, several sections provided for the arrangement and character of the buildings to be used in the housing of men and animals and the sanitary conditions of the same with proper and suitable means for ventilation and prevention of fire; other provisions specified that wash houses, and stables should be kept separate from kitchen and from sleeping quarters. The contractor was also obliged to furnish pure drinking supply for employees from an approved source and to satisfactorily and thoroughly dispose of food and kitchen waste and all garbage, so as not to crate a nuisance. The sanitaries, even in this work of temporary character and subject to shifting from place to place, were required to be maintained in a satisfactory manner, without causing a nuisance. Medical inspection and the installing and equipment of a field hospital was further required.

The City of New York in the large works for a supply of water from the Catskills, following the Pittsburgh work some three years later, incorporated these same sort of requirements, somewhat more explicit and defined that such beneficial provisions thus undertaken should have definitely itemized payments as completed. This removed all the sting from the doing of such humane things, for previously with no payment for each thing done, the contractor was prone to believe that it was necessary and viewed the cost as money wasted and any expense that he could avoid was so much to the good. With a definite provision for payment, however, there is no reasonable excuse for doing anything but the very best and most complete work.

Whatever we may feel and believe about such provisions from the humane standpoint the ultimate criterion from a business man's point of view is, will it pay, and I think we can assuredly answer yes. The experience of the army and of those

companies that have properly taken care of such matters is ample testimony along this line. However, the coal operator and the manager is intent upon getting out the product and is apt to think only of this, it is therefore very wise that the carrying out of such sanitary provisions should be left to another force, entirely independent from operating management and reporting directly to the highest administrator. This is the method employed upon the Panama Canal, where the sanitation and medical work is in charge of a definite and separate organization, the head of which is a member of the Canal Commission. This is also the method adopted by the New York Board of Water Supply, in which the general supervision of such work is under the guidance of an outside agency reporting directly to the Board. In this way, the men who's attention is strictly paid to tonnage and intent upon each month's output being greater than that of the preceding month and who thus are apt to mimimize necessity for adequate provisions for public health, are relieved of this work and an authority of great effectiveness, fully alive to the responsibilities has entire control of these matters; to the great advantage of the work as a whole and the continued efficiency of the force.

One of the most notable examples of thoughtful care in this line has been the recent activity of the Alabama Coal Operators' Association. As previously stated, there have been single instances of operators and companies realizing and rising to their opportunities, but this is the first occasion so far as the writer knows, in which a group or organization have undertaken a concerted and scientific study of the conditions which will promote sanitary, health, social and living welfare of the employees and their families. The following is a copy of a notice recently issued by this association to the members:

"The Alabama Coal Operators' Association during the last two years has, through its organization and through the individual efforts of its members, given considerable attention to the subject of accident prevention both on the surface and underground. This work has been supplemented by the organization and training of a number of First Aid Corps. At the annual meeting of the Association last August the subject of Tuberculosis was given special consideration, particularly those features relating to ts prevention and cure in its early stages.

In extension of this general policy the Association has just engaged in making a social and sanitary survey of the Coal Mining Camps represented in the organization. The work as outlined is rather comprehensive, embracing housing conditions, the more strictly fundamental sanitary features including drinking water supplies, closets, sewage and garbage disposal, etc. The rather difficult problems of education and recreation will also be given proper consideration. As a result of concerted effort along these lines, it is hoped that living conditions throughout the State will be such as to entitle Alabama to first rank in matters of this character."

In explanation of the above it may be well to state that it is expected that all of the factors, water supply, disposal of human and other wastes, etc., shall be thoroughly studied and chronicled, with a further expectation of working out and suggesting ample provisions for improvement of water supply and for adequate, safe and sanitary disposal of wastes. Much can be done with the present facilities to improve their maintenance and care, also if copious and ample single sources of water supply are not feasible to so locate and plan wells that they cannot be contaminated by surface or soil pollution. It is also intended to study into the commissary conditions, especially relating to milk, meat and other supplies easily effected by unsanitary conditions. The general health organization and conditions, including medical, hospital service, with changing houses and baths are all to have their proper consideration. In addition to this the character of the facilities for housing, schools, churches, entertainment and recreation are all to be studied for the purpose of learning the fundamental requirements which make for contentment and happiness of the employee, and do away with the inefficiency that follows rest periods, with the accompanying excesses in intoxicants and other abused forms of pleasure. It is expected that if such be thoroughly done and the wrongs eradicated this same contentment will promote, by permanent living in one place, continuance of employment and lack of indifference of men following pay days and Sundays. It is hoped that this pioneer movement on such a large scale will afford an excellent opportunity to show the usefulness of the many things which have previously been attempted in a small way by individual concerns, some without proper relation of one factor to

another and without an understanding of the fundamental requirements of such a movement and some with a tendency to pay more attention to surface and appearance of things than to correcting and improving those important matters of safe and convenient water supply and sanitary and wholesome disposal of wastes.

Mr. Geo. S. Rice:* The ideas presented by Mr. Knowles are very striking. The suggestion furnished by the method employed on the Panama Canal, of having the sanitation and medical work in charge of a separate organization, independent of the construction operations, appears to me to be admirable and one that could be adopted with advantage by all large mining companies.

The resident engineer or the mine superintendent is expected to get results quickly. If his attention is diverted from the construction or mine development to see that houses are built with regard to sanitation or attractiveness, assuming he has the knowledge to supervise, then his mining work is likely to suffer.

It is, therefore, much better to relieve him altogether of the responsibility and have an independent organization reporting to the head officials, handle such matters. Only in this way can house-planning, sanitation, and landscape gardening for our mining towns be raised out of the terrible slough of the unsightly, fire-inviting houses of the average mining town with its insanitary and unattractive surroundings.

In regard to mine sanitation, it may truthfully be said, there is no such thing in this country. Fortunately the great majority of our mines are cool, unlike the deep, hot and humid mines of Germany.

There, some years ago, the hook-worm disease (ankylostomiasis) reached serious proportions and at one time over 50 percent of the miners of Westphalia were affected. By rigid sanitation regulations including the required use of sanitary cans placed at certain distances from the working places, isolation and hospital treatment of those affected have reduced the pro-

*Mining Engineer, U. S. Bureau of Mines, Testing Station, Pittsburgh.

portion to about one percent. When a miner applies for work, he is carefully examined by the medical attendant, if accepted a weekly examination follows for a considerable period, then occasionally. The government regulations tend to make the companies very strict, for if a man is found affected he must be sent to the hospital at the company's expense, and they must pay him in addition two marks (50 cents) per day.

While this disease is not yet of alarming proportions in this country, as it is very contagious, it is liable to become so at least in the warmer, damper mines. A government representative in a recent investigation found a considerable prevalence in southern mines. Mine sanitation is therefore asuming a new importance to the mining engineers of this country.

Mr. G. E. Flanagan:† It seems altogether probable that there is not a word in the English language the meaning of which has undergone greater expansion in recent times than the word "engineer." Only a few years ago at one of our banquets a member gave a list of the engineers represented by our Society, some 350 or more at that time, in which the mining engineer was mentioned as one. Tonight a prominent representative of this branch characterizes the mining engineer as composite photograph of the entire society. He is not alone in this. Many of us who labor along other lines have often felt that if we could combine the mental equipment of our fellow members with what we may have of our own, it would be none too much for the task in hand. The steel works engineer experiences this feeling in its greatest intensity.

It is a rather interesting conception, that of the mining engineer as the composite photograph of the mental activities of the thousand or so members of this Society. To mentally picture this one would have to imagine some radio-active force emanating from a center, gathering impressions from sources almost infinite in number and returning to concentrate them within the compass of one poor human intellect.

I would like to ask one or two questions of the members who have discussed this paper from various standpoints. Ex-

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plosives have been referred to for breaking down the coal, and I have in mind that there has been introduced a hydraulic device for this purpose after the coal has been undercut by machines. A description of such a device would be interesting to me, and possibly some of the other members present, who perhaps know as little about it as I do.

And another question: Mr. Fohl referred to two coal seams here. It occurred to me to ask whether or not there are other seams in this neighborhood of still greater depth, which might be a matter of interest.

The question that Mr. Lewis dealt with, regarding building material, called to my mind the device for applying cement and sand in spray to a thickness of from one to one and one-half inches, for preserving a steel frame. Is there anything in this idea that would make it anything like equivalent to the life of a reinforced concrete structure?

Mr. J. S. Unger: Some experiments have been made where steel was coated with a very thin cement wash and whitewash, to assist in preserving it from corrosion, and the results were very unsatisfactory. The material did not adhere to the steel at all. I think it was a matter of about twenty days until the cement wash had peeled off altogether.

Mr. G. E. Flanagan: Is there another seam of coal that has not been worked?

Mr. H. J. Lewis: Well, the Freeport has been worked. From the Pittsburgh to the top of the Freeport is about 640 feet, but I think that is a variable amount, probably a little less than that.

Mr. S. A. Taylor: The upper Freeport Coal, which is the next workable seam below the Pittsburgh, is from 500 to 600 feet below it. The next workable seam below the Upper Freeport in this district is the Lower Kittanning, and is from 150 to 190 ft. below it. These two seams are generally the only workable seams in the Allegheny series in this neighborhood.

CORRESPONDENCE

Mr. R. B. Woodworth:* Mr. Fohl in his very admirable statement of the engineering problems in coal mining operations has not referred to the assistance the structural engineer may be called upon to render underground. He has asked what the structural engineer proposes to do for the mining industry in the construction of tipples, headframes, washing plants, etc., above ground, and the inference is that in his purview of the situation the activities of the structural engineer are to cease at the pit or shaft mouth. I do not think Mr. Fohl intended to convey the impression that the structural engineer was not allowed below ground or that there was not a field for his abilities in the actual carrying on of mining operations proper. It is true that the methods of the structural engineer are not as a rule underground; his operations are carried on generally in the light of day where his mistakes can readily be seen and his merits justly appreciated.

I do not consider that the structural engineer has completed his work when he has erected all the above ground buildings. I think that there is a place for him in the timbering of the shaft and in the proper supporting of the side walls and the excavations made for headings within the mine itself. The need for his services underground in the proper timbering of the mine arises from just those circumstances which have been referred to as calling forth the abilities of a real mining engineer who will do something more than dig and load coal at the face. The placing of the business of mining on a scientific basis means everywhere the replacement of brawn by brains; the elimination of rule of thumb methods and their substitution by those which are scientific and therewith the painstaking conscientious attention to details which go to make mining profitable.

It is true that years ago the mine timbering problem was a comparatively simple one. Its importance is thrust upon us today by the increased depth and length of workings, the enormous consumption of wood necessitated by the continuous pursuit of old time mining methods and the short life of wood

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when subject to stress under heavy loading conditions, variable temperature and large moisture content of mine air. While the cost of the above ground buildings is a permanent charge carried into cost of plant, and, therefore, treated as an overhead expense subject to the usual allowances for depreciation, etc., the net proportion chargeable to each ton of coal mined is small and decreases with the output of the mine. The cost of mine timbering in wood, however, is an increasing expense as the operations extend and as replacement becomes necessary. Each penny invested in mine timbering in wood must, therefore, be charged to the cost of maintenance, replacements, renewals and extensions allowed for so as to become fairly constant for each ton of coal mined regardless of the output. This charge per ton of coal mined amounts, according to the best computation, to about seven cents per ton in the anthracite region, and to between four and five cents in the bituminous region, and under present conditions of wood supply is likely to increase rather than diminish in the future. To reduce this charge to its lowest possible dimensions and, therewith, to effect the largest possible measure of economy in the actual cost of production merits the careful attention of the mining engineer and affords a problem whose solution demands the expert services of the structural engineer as well.

The importance of this problem is seen also in the new methods which have come to the front as means for the production of coal without the use, or with a minimum use, of mine timbers themselves. In the mining of iron and other metals top slicing and sub-slicing methods have come into use, with other expedients whereby the ordinary methods of supporting roofs are eliminated. In coal mining, excavation by means of rooms and pillars is giving way to long wall methods of mining, and American practice is, therefore, more nearly approaching conditions in England and on the European continent where of necessity attention to the saving of timber has for long years been paid. We hear also of expedients for the filling of the rooms with culm or clay so as to permit the safe robbing of the pillars.

All these methods of course have their place, and from the

standpoint of the conservation of resources it is required that we utilize wherever possible such expedients to minimize the cost of production coincident with the increased safety of the miner and the decreased possibility of subsidence above ground which would affect buildings and other property whether owned by the mine operators or otherwise.

It is probable, however, that as long as coal is mined there will be necessity for some method of supporting the horizontal excavations either by means of wood or steel or concrete or some other substance, and if the model mine of the future is to be economical, its timbering must be carried on in a scientific manner. I am not now speaking of vertical excavations. I think that we will never reach a point where it will not be necessary to frame the shaft itself in such a way as to secure permanence and safety, but I may say that the timbering of all excavations is in a way subject to the same rules and is to be carried out by the use of the same methods whether the excavation is vertical or horizontal, whether the structural engineer is called upon to frame a shaft, a slope or a horizontal heading.

I am not here to say that the use of any one material will satisfy all of the conditions so as to produce the greatest possible return on invested capital for the minimum of expenditure, but I do say that the problem involves the scientific study and use of the materials of construction which is essentially the work of the structural engineer, and I may also say that the structural engineer will guarantee to solve that problem in any particular instance in the most economical and satisfactory way if the responsibility is placed upon him.

Premising that we are all of us satisfied that the days of wood for mine timbering operations are numbered when permanance and ultimate cost of construction and maintenance are taken into account, and that the experimental use of concrete in timbering horizontal headings has not been attended hitherto with that large measure of success or satisfaction which ought to accompany the use of an ideal material of construction, I may be permitted to say a few words on the use of steel underground, in which I have had some small experience.

The first use of structural steel in the mines, of which I have information, came as far back as 1876 in the Cambois Colliery in England and the conditions which called for its employment were wide spans and heavy loads, to support which safely wood was not sufficient. The same considerations underlie its use in 1897 at the foot of Stearns Shaft of the Susquehanna Coal Company and in 1897 at the Hazleton pump house of the Lehigh Valley Coal Company, which is the earliest example of the steel framed concrete lined pump house, to my knowledge, in the United States. Earlier than this, in 1896, the fire risk, which is the second main consideration for the use of steel underground, led to its introduction in Mine No. 1 of the Spring Valley Coal Company, Spring Valley, Ill.

These two considerations of heavy loads and fire protection still apply when the structural engineer considers the situation, and the fact that these three installations have been successful, doing their work without replacement and without serious deterioration for 15 years, gives the structural engineer firm assurance when he undertakes to timber a mine to last for the length of time Mr. Fohl requires and makes him confident that he can do again and do well what he has already done.

It may be said that "of course the structural engineer will use steel underground, just as he uses steel above ground, where he cannot use wood on account of its weakness," and we, therefore, come to the next consideration, that economy in expenditure makes steel a great deal cheaper than wood even in such situations where the strength of the latter is sufficient. It was on this basis that the Carnegie Steel Company in 1894 made its first proposals for the replacement of wood by steel in mine timbering operations, and the comparative cost and the relative durability of the two materials must be today those factors which will guide the structural engineer in his decision as to what he ought to use in any particular instance. It must also be said that each particular instance must be given its own special treatment. The structural engineer would be foolish to use steel for supporting excavations in the caving system of iron ore mining where

it is the expectation that the wood which is used will be crushed and broken and come down with the ore itself, to be carried out of the mine unfit for further use. He will also be foolish to use steel for props where he expects the props to remain in place and to be broken when the roof falls. In both these directions, however, the American engineer can safely and wisely take a leaf out of the English engineer's book and figure on the removal and re-use of a very large portion of his props rather than their ultimate destruction, and if he so does, the chances are he will find the use of metallic props just as economical in the United States of North America as they have been in England and and in the mines of France and Germany.

The strength and stiffness of steel for mine timbering purposes, its advantages from the standpoint of durability, fire protection, re-use, etc., are theoretically unquestionable. Is its use economical and does its employment serve to reduce the cost per ton of coal mined? The conclusion that it does produce these very results can today be supported by ample evidence. Two illustrations of the successful recent use of steel may suffice.

The Dodson Colliery of the Plymouth Coal Company is the place at which culm flushing was first tried out in 1891 under the direction of Mr. John C. Haddock, now president of the company.

At this colliery the timbering of the pump room, which is 100 ft. long, eight feet high in the clear and 18 to 22 ft. wide, has been a matter of difficulty owing to the movement of the strata above it. The original wooden timbering consisted of 18 to 22 in. round sticks of yellow pine and oak placed two feet center to center, and even with this close spacing, practically skin to skin, there was difficulty in holding the roof from closing down upon the pipe lines. It is estimated that the entire pump room was retimbered in wood once a year.

Beginning with April 16th, 1910, and extending to December 15th, 1910, the 70 wooden sets of mine timbers were replaced by 48 steel sets made up of 18 and 20 in. I-beam col-

lars and six inch H-beam legs. The total cost for timbering once with wood was $2,415.00 and the total cost for timbering in steel $2,889.09, or a difference in first cost of not quite 20 percent. The steel cost at the mines slightly over two and a half times the cost of the wooden sets and it also cost 33 1-3 percent more for placing. Fewer sets were required, however, and the ultimate rate was thereby lessened.

The comparative cost of the two installations in detail is shown in statement below prepared by Mr. Haddock himself:

WOOD		STEEL	
Number of sets	70	Number of sets	48
Average diameter of timber, inches	20	Size of collars, 18 in. beam, pounds	55
		Size of collars, 20 in. beam, pounds	65
Quality of timber—yellow pine and oak.		Size of legs, 6 in. H-beam, pounds	23.6
		Quality of steel—structural grade.	
Average weight per set, pounds	4,150	Average weight per set. pounds	1,483
Cost per set f.o.b. cars mine	$12.00	Cost per set f.o.b mines	$31.47
Cost per set for placing	$22.50	Cost per set for placing	$30.00
Cost per set in place	$34.50	Cost per set in place	$61.47
Total cost for timbering	$2,415.00	Total cost for timbering	$2,889.09
Life of timber set, year	1		

The higher cost of placing the steel was due to three causes:

1. The charge for taking out the old timber and placing the steel a set at a time by forepoling ahead, this method being pursued on account of the condition of the roof and the quantity of loose material for an unknown distance above.

2. Great care was taken with the steel to line it up properly and to provide a good base, which is made of a solid concrete wall built the full length of the pump room on each side. This solid concrete base is unnecessary with wood and might have been omitted with the steel but its use means a real betterment in construction.

3. The steel was placed without interfering with the operation of the pumps, which necessitated very careful handling and added something to what the expense would have been had the room been free from obstructions.

It is apparent that while the first cost of the steel construction is greater than that of the wood, it will have paid for itself

if its life extends over 15 months only, and every additional length of time it stands will mean that much less in cost of maintenance. The first steel sets have now been in use 19 months without any signs of deflection in the collars, and, what is better, with no evidence of fracture in the concrete where overloading would immediately show itself.

The Dodson Colliery, as is well known, is located in the anthracite region where, as a rule, the strata are steeply inclined, squeezes frequent and loading conditions severe.

The representative bituminous mine timbered with steel timbers is the No. 8 mine of the West Kentucky Coal Company at Sturgis, Ky. This mine is in the No. 9 seam of the western Kentucky coal measures and the coal is 4 ft. 10 in. thick. Steel mine timbers are used in the new slope both in the main heading and in the air course, and the detailed comparative statement which follows is furnished by W. H. Cunningham, General Manager:

YELLOW PINE CREOSOTED 12 LB. PER CUBIC FOOT

Cap 12 in. by 12 in. by 10 in. Struts 2 pcs. 12 in. by 12 in. by 6 in.	264 ft. B. M.@$40.00—$10.56	
Labor handling and framing same	@$10.00—$ 2.64	$13.20

Approximate weight per set, 1,575 lb.

NATIVE WHITE OAK TIMBER SET

264 ft. B. M.	@$30.00—$7.92	
Labor handling and framing same	@ 10.00— 2.64	$10.56

Approximate weight per set, 1,340 lb.

STEEL MINE TIMBER SET

Style F	10 in. I—25 lb. 10 ft. long Struts 4 in. H-13.6 lb. 6 ft. long f. o. b. Sturgis, per set	$9.75

Safe uniform load 12 by 12 in.—10 ft. span—19,200 lb.
Safe uniform load 10 in. I-25 lb.—10 ft. span—26 050 lb.
Safe uniform load 12 by 12 in.—6 ft. long—105 120 lb.
Safe uniform load 4 in. H-13.6 lb.—6 ft. long—43 220 lb.

Concrete per foot in place, labor.....	$ .44	
Concrete per foot in place, material	1.28	$1.72

Sets three feet centers.

Concrete per set in place	$ 5.16
Cost of steel set f. o. b. Sturgis	9.75
Handling and setting	1.00
TOTAL PER SET IN PLACE	$15.91
Cost of White Oak Set	$10.56
Labor setting	2.50
TOTAL PER SET IN PLACE	$13.06
Saving Steel over Oak—without concrete	$2.31
Excess Steel with concrete over Oak	$2.85

It will be noted from the above statement that this comparison between steel and wood is based on the use of native white oak framed in the usual way while the steel sets are put in with a concrete base, that the steel set is 40 percent stronger than the wooden set which it displaces, and that without the concrete, which is put in for permanence, the steel set is actually cheaper than the oak and no dearer with the concrete than a yellow pine set installed in the usual manner. The relative cheapness of the steel is due to the fact that by its use the strength of the legs may be more nearly adjusted to the strength of the collar, and waste thereby eliminated, than is possible with the use of wood where the legs are made of the same dimensions as the collars. While this showing is very favorable to steel, it can be duplicated by the records of many similar installations, all of which agree in the conclusion that for timbering headings, pump rooms, etc., there is a distinct economy in the substitution for wood of steel, either in first cost or in ultimate expenditure.

The situation is not essentially different in shaft work. There are in the iron mining region numbers of shafts framed with steel and lagged either with wooden sheeting or concrete. The use of steel, however, in a shaft is dependent somewhat on the kind of a shaft that is to be framed.

The circular shaft is common in England and on the European continent though practically unknown in America, the writer having only come across two circular shafts in the whole course of his experience and investigation. American mining practice has never taken kindly to the circular shaft and has not done so largely by reason of the cheapness of wood with which

most shafts are framed in this country and which is not adapted for circular framing. A circular shaft is usually lined with brick or cast iron segments, and while it is possible to line a circular shaft with all steel segments, it has only been done in a few cases. Concrete is a much more available material for circular shaft lining and doubtless would be used, either reinforced or otherwise, in this country were circular shafts in use.

Concrete, whether reinforced or otherwise, does lend itself to the construction of the elliptical shaft and most, if not all, of the concrete shafts which have been sunk have been of that shape. The concrete is preferably reinforced and the buntons, compartment separators, etc., made of steel either exposed and painted or encased with concrete casing. A shaft built in this way combines the strength and advantages of both materials.

The rectangular shaft is the standard shaft in America for the reason in the first place that it is the most economical in point of excavation, and in the second place because that form of shaft has been most conveniently framed in wood, which is best adapted to rectangular framing, and so long as the hoisting cages are rectangular, so long will the rectangular shaft retain its position in American mining practice.

So far as the methods of construction are concerned, steel is the only material perfectly adapted to take the place of wood in rectangular framing. It sustains loads in tension, compression or bending in the same manner and under the same conditions of internal stress. It is, therefore, admirably fitted in every direction to serve the purposes of the structural engineer in the shafts of the future because its use means no departure from established methods of operation and no uncertainty as to its durability.

So far, however, as the lagging of the shaft is concerned, economy may be found in the use of concrete slabs of sufficient strength to carry the transverse pressure from one set of shaft timbers to the next, and such a construction has been advocated by the writer as the ideal form of shaft construction, the strength and stiffness of the steel being relied upon to resist the combined compressive and cross bending stresses which occur in mine shafts, especially when sunk through inclined strata or

on an incline itself, while the durability of the concrete makes it a suitable material for the replacement of the ordinary wood lagging.

While it is not possible to compare costs of sinking shafts in different localities very closely with each other on account of the variable conditions which are found in the character of the strata, the hardness of drilling, etc., the steel framed concrete lagged shaft has shown its relative efficiency and economy in a couple of shafts which have come to the writer's notice.

In the mines of the Consolidated Indiana Coal Company, at Dallas, Iowa, for example, such a two-compartment shaft has been sunk 125 feet to rock at a cost, including labor and material, not to exceed $60.00 a foot. The steel work of the shaft is carried by heavy channels framed on the surface and supported at intervals by short struts running into the rocks which are framed in the back flange of the I-beam stringers which form the shaft sets proper. Concrete can be put in at any section of the shaft, as the bents are about five feet apart and each section is practically self-supporting. The design of this particular shaft is patented by Mr. Carl Scholz, Vice President and Chief Engineer of the Company.

The sixteen years of service which steel has already given in the mines of the United States and the much longer term of service it has given abroad is a sufficient demonstration of its durability, on which its economic use so much depends. Of course no one in this day and generation thinks of placing steel in any situation without proper protection against corrosion and this feature has been given very careful attention. It has been demonstrated by laboratory and field tests as well that the time honored method of the preservation of steel from corrosion by the use of a good red lead or other metallic pigment is amply sufficient for mine timber purposes, especially if the first inhibitive coat put on in the shop is followed by the use of a good excluder, such as graphite, at the mines. Within the mines and apart from the mere action of mine water the conditions are very much better for the preservation of corrosion than they are outside. The paint coating is not subject to the action of strong sunlight and the abrasive action of wind and dust or to

the disastrous effects of sudden changes in temperature. The paint coating once put on well will need no renewals for years and in fact the writer knows of one instance at least where steel has been in use 15 years without repainting. The effect of mine water has been very much exaggerated. In most mines the free sulphuric acid content is not of sufficient magnitude to cause any deleterious action on a paint film at all whatever might be its effect on raw steel, and even the action of water with a relatively high free sulphuric acid content can readily be met by the use of the pigments already mentioned well applied.

The structural engineer, therefore, stands ready to lend his asisstance to the mining engineer in his underground operations whenever he is called upon so to do, with full assurance and confidence that he can solve the latter's mine timbering problems for him and do it with the minimum expenditure and the least possible cost in maintenance.

METALLIC ROOFING

By D. M. Buck*

In taking up the subject of "Metallic Roofing" we will confine ourselves in this paper mainly to the discussion of those forms of roofing made from steel or iron, rolled into sheets in the usual manner, annealed to give the proper softness and ductility, and coated with various substances for the purpose of excluding air and moisture from the underlying base metal of the sheet.

The three most important classes under this main heading are Painted Black Sheets, Galvanized Sheets and Terne Plate.

The first mentioned, as the name indicates, is a black sheet of steel without any metallic protective coating, but covered with a coating of a good grade of paint before leaving the mill.

Galvanized Sheets are made by passing the black sheets, after the surfaces have been thoroughly cleaned and prepared, through pure molten zinc. By this process the surfaces are uniformly covered with an adherent coating of zinc, which entirely excludes the oxygen and moisture of the atmosphere, and inasmuch as the solution pressure, or, in other words, the corrodibility of zinc is very low, the life of such a sheet under weather conditions, even without being painted, is remarkably long. In addition to the direct exclusion of the elements, zinc has another property which makes it an excellent protective medium for iron and steel. I refer to the well-known fact that zinc is "electropositive" to iron or steel, and wherever the two metals are exposed together the difference of potential between the two metals tends to protect the iron or steel at the expense of the zinc. This is easily illustrated by shearing off the covered edge of a Galvanized Sheet and exposing the raw edge to the weather. After months or even years' time an examination of this raw edge will show that no corrosion whatever has taken place, and

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although the action of the zinc itself at the point of contact has been somewhat accelerated, yet the natural low corrodibility of zinc causes this action to be very slow; and although the ultimate life of a sheet where the under-lying metal has been laid bare is, of course, less than the one perfectly protected, yet the electrolytic protection above mentioned will, as above indicated, preserve the metal for a considerable length of time.

Galvanized Sheets, Painted Sheets and Black Sheets Unpainted are furnished by the average manufacturer in nearly any gauge or size, plain or corrugated, or V-crimped, and also in the form of "Roll Roofing", so that it is possible for a consumer to procure almost any form desired.

Terne Plate is made by passing thoroughly cleaned steel plates through molten terne mixture. This terne mixture is an alloy of pure tin and pure lead in varying proportions, the most common mixture being 27 percent tin and 73 percent lead. When plates emerge from the bath of molten metal they are thoroughly covered with a fairly uniform coating of this alloy. Since terne mixture itself is practically incorrodible one may expect long service from a roof formed of this material. Terne Plates are furnished commonly in sheets 20 by 28 in., 112 sheets to the box, but as is the case with Galvanized and Black Sheets it is also furnished in the form of Roll Roofing where the sheets are soldered on the ends and ready to roll out on the roof and fasten at the sides in one of the well-known methods of flat seam or standing seam construction.

Steel or iron is an excellent material for using as a base in the manufacture of roofing sheets, inasmuch as it has in itself nearly all of the properties required for roofing material. It is strong, ductile, rigid, impermeable to rain, snow, storm or sun, and is fire-proof. But is is corrodible and must be protected from the action of oxygen and moisture. This is true of all iron or steel no matter what the composition or what name is given to the product. Any unprotected iron or steel, if exposed to the weather, will form a film or red rust on the surface after the first rain.

The Engineer in constructing a tall office building employs in the frame work the best material available for the purpose

to give the strength, rigidity and carrying power necessary to sustain the building. This material is, of course, structural steel. But he also knows that this material must be protected from corrosion and he, therefore, covers it and protects it from the atmosphere with concrete, tile or some other of the well-known materials of construction.

So in the building up of a roofing sheet the basic structure of the sheet, i. e., iron or steel, is always covered either by the manufacturer or by the consumer with some film which will exclude air and moisture. It would be ridiculous to expose any iron or steel sheet to the weather without such protection.

One sometimes hears the statement made that roofing sheets manufactured today do not "last" as long as those which were obtainable in former times. This impression is entirely erroneous and is, no doubt, explained by the fact that against the advice of honest manufacturers the tendency has been in recent years towards the use of lighter and lighter weight sheets until today roofing of entirely insufficient weight has been substituted to an alarming extent for the heavier weights more suitable for permanent construction.

This rather reprehensible practice can, no doubt, partially be attributed to the dishonest contractor, who has substituted lighter weight sheets than his employer had a right to expect. It is also partially due to a tendency on the part of the builder to secure an extremely low first cost.

In any case we wish to strongly condemn this practice and to go emphatically on record that sheets are made today by reputable manufacturers and are procurable on the market at least as good from point of actual service as any that have been manufactured in the past.

The advantages of metal sheets for roofs over other forms of construction are so numerous that we will only mention a few of the most important ones at this time.

Owing to the widely varied forms in which sheet metal can be obtained, it is possible to construct from metallic sheets practically any type of roofing,—from the flat or nearly flat construction to those of the steepest pitch.

In the use of corrugated Galvanized or Black Sheets the

additional strength and rigidity imparted to the sheets by the corrugations makes it possible to use this form without any underlying sheathing or roof construction except the purlins themselves, thus considerably reducing the ultimate cost of the roof and at the same time procuring by the use of proper gauges a roof fully as strong as other types requiring foundation sheathing for the roof surface material.

This same advantage is present to a greater or less extent in the use of flat or uncorrugated sheets either Galvanized or Terne Plate, since the practically continuous sheet formed by soldering and seaming presents a light, strong and more or less rigid construction capable of being applied to a skeleton frame and not requiring a solid wooden sheathing as is necessary for most of the other forms of roofing construction.

As mentioned above sheet metal is impermeable to the weather and is not injured by hailstones nor readily damaged by any falling body. On the soldered and seamed construction generally used on flat roofs there are no cracks for snow to sift through. Sheet metal roofs are absolutely incombustible and, therefore, fire-proof.

Tin covered fire-doors and shutters are the highest type recommended by the best authorities in the land, and metal roofs have recently been rated as the highest form of roofing by the National Fire Protection Association after years of experiments and tests with various other forms of roofing, including slate.

A metal roof properly laid also prevents the passage of flames from below and thus will for a considerable time retard the ferocity of a fire started from within.

In the case of wooden shingles and slate a high wind often exerts force enough to strip the roof of its covering. This cannot take place on continuous metal roofs. Metal sheets will not curl up as is the case with wooden shingles and will not crack from impact or from the expansion and contraction due to changes in temperature.

Metal roofs are more easily applied and the first cost of installation is, therefore, considerably lower than that of any other type of permanent roof construction.

In the case of shingles and slate a leak once started is often very hard to locate and difficult to repair. This is also especially true in the case of the so-called "built up" roofs. In this type water often gets between the layers of felt and by the alternate freezing and thawing in the winter works itself to remarkable distances between the layers, causing blisters, and it is usually very difficult to trace and repair a leak in a roof of this character. A leak in a sheet metal roof is usually very easy to find and can be repaired at a low cost in a very short time.

Metal sheet roofs are clean and sanitary, so that where necessary water from them can be collected into cisterns used for domestic purposes. Having no gravel and tar the surface is not so apt to clog up eave trough and conductor pipes as is often the case with so-called "slag" roofs.

The feature of the weight of a roof is often overlooked. This is an important advantage of tin roofs. For instance, 100 sq. ft. of I. C. Tin laid with standing seam weighs about 65 lb. as compared with 400 lb. for wooden shingles, approximately 400 lb. for 3-ply slag, 500 lb. for 4-ply slag and 650 lb. for slate. Thus it can be readily seen that the lower cost due to lighter construction necessary in the frame work for supporting walls to bear a sheet metal roof must be taken into consideration.

Considering the subject from all stand-points we believe that metal sheets for roofs are not surpassed, if equalled, by any other form of construction, and we believe we are correct in saying that, considering either a temporary or permanent roof, the lowest cost per year of service can be had by the use of metal sheets.

Tests have been proposed and advocated by some manufacturers for the quick determination of the probable life of metal sheets in service. None of these have so far proven of any value whatever, but the one which has become most generally known is the "accelerated acid test." This consists in exposing portions of a Black Sheet to 25 percent sulphuric acid and noting the relative loss of material in solution. In other words the test is based on the solubility of the material in sulphuric acid.

The writer has made many experiments which prove the

utter fallacy of this test as a direct measure of corrosion, and nearly all of the investigators of this subject have come to the same conclusion. This resistance to the action of acid in certain products is obtained by the introduction of small amounts of copper into the molten steel, and if, for any reason, resistance to acid is desired, or the consumer wishes to purchase material on the basis of such resistance, material is furnished by the average manufacturer today which contains this small amount of copper and which will resist acid to an equal or greater extent than any of the widely exploited products.

It is absolutely necessary to paint the Black Sheet to protect it from the weather and it also affords additional protection of considerable value to coated sheets. The subject of the proper paint for a Black or Coated Sheet is one well worthy a separate paper and will not be discussed by the writer at this time. Many tests are being made by eminent investigators along this line and much good has already come from their reports and more can be expected in the future.

DISCUSSION

Mr. J. A. Aupperle:* Experience teaches that there are ten fundamental principles which every engineer considers most carefully before drafting specifications for a roof. The ideal roof must conform to all the following requirements:

Weatherproof.
Fireproof.
Minimum weight.
Maximum strength.
Provision for expansion and contraction.
Low first cost.
Simplicity and low cost of application.
Low insurance rates.
Minimum cost of maintenance.
Long life and durability.

There are many excellent grades of roofing which fulfill some of these requirements perfectly, but a systematic, thorough comparison of all grades, proves most conclusively that metallic

*Chief Metallurgical Engineer, American Rolling Mill Company, Middletown, Ohio.

roofing, as manufactured from the pure iron, conforms to all the requirements and meets every condition better than any other kind of roofing manufactured today. The following facts will demonstrate how uniformly the pure iron roofing meets each important requirement.

Weather Proof: The many different styles of metallic roofing permits its application to all kinds, shapes and forms of roof construction, providing the necessary and satisfactory grade for each particular roof, and the variation in pitch.

The joints are soldered, double-seamed or lapped so snugly that they are perfectly water-tight. Driven snow cannot penetrate these joints, and they are impervious to capillarity, which, in freezing weather, plays such havoc with slate and tile roofs.

Because of the large sections in metallic roofing, there are less seams and joints exposed than in practically any other grade and there is absolutely no absorption of moisture. Therefore, a metallic roof is perfectly weather-proof when properly applied.

Fireproof: From a fireproof standpoint, metallic roofing is the peer of all roofing. It is not only absolute protection against fire from without, but holds and smothers the fire within, thus preventing the flames from spreading to adjacent buildings.

The lightness of this roofing obviates the danger of a heavy roof crashing through the building before the supporting timbers are half consumed.

It may be coincidental, but an investigation to learn the effect of lightning upon metallic roofing, resulted in the discovery that, of the many consulted, there was no record of a metallic roof having been struck by lightning.

Page 702, of Foster's Electrical Engineers Pocket Book, contains the following statement: "A sheet of copper, a sheet of iron, a tin roof, if without breaks and fully connected by well-soldered joints can be utilized to advantage as lightning conductors." Many architects take this into consideration, making the eaves trough and downspouting form a perfect connection to the earth.

Weight: Comparing the weight of metallic roofing with

all other roofing, proves that it is as light as the very lightest forms, and very much lighter than the more substantial forms of roofing, such as slate, tile and concrete. As an example, 20 gauge corrugated roofing, galvanized, weighs 1.78 lb. per sq. ft. A reinforced tile roofing weighs 13½ lb. per sq. ft.

This introduces one of the strongest features in favor of metallic roofing, vlz. the great saving in the cost of the superstructure. All corrugated roofing can be applied directly to the purlins. *V*-Crimp, Pressed Standing Seam and Roll Roofing require a very light sheathing, while in all cases a very light and less costly super-structure is perfectly adequate.

Strength: In this respect, metallic roofing again excels, presenting the very strongest form of roofing obtainable. This feature is of the utmost importance, when wind-pressure, snow-loads and walking upon a roof, are taken into consideration.

In practically all forms of metallic roofing, the seams and joints are interlapped over the entire surface, and the straps and cleats are in no wise exposed. This construction has two important advantages. 1st: The fastenings are not subjected to deterioration, and no part of the roof is dependent upon one, or a few, fastenings which may give way, cause breakage and leaks as in tile and slate, but all the fastenings act as a unit in keeping it in place. 2nd: It is absolutely impossible for the wind to get under it.

Very few roofs are constructed, over which it is not necessary for some one to walk at one time or another, and no roof offers better resistance to this kind of abuse than does the metallic roof.

Corrugated roofing, because of the known tensile strength of iron and the strength imparted by the corrugations, is not only self-supporting, but is undoubtedly the very best form of roofing for large structures, mills and factories of all kinds. It is the strongest roof made.

Expansion and Contraction: The extremes of heat and cold are amply provided for in metallic roofing. The corrugations, seams and joints are all constructed to meet this particular requirement. It is, therefore, impossible for it to crack or pull apart, but on the other hand, it gives and returns with-

out injury to the efficiency of the roof, or tearing away from the fastenings.

First Cost: According to the demands and requirements of the trade, metal roofing gives as low, if not a lower, first cost, due to the low price of the material itself. The ease and simplicity of application emphasizes this feature, and it possesses the minimum possibility of poor workmanship.

Insurance: The highest tribute to metallic roofing is presented by the insurance writers. In this respect, it represents a great saving, because it receives the lowest rates. The fact that the National Fire Protective Association places metal roofing first, proves its great superiority from a fireproof standpoint.

Minimum Cost of Maintenance: The first cost can only be correctly computed by anticipating the cost of maintenance. Those roofs which often appear cheapest are, in the long run, most costly. Because of the excellent features found in metallic roofing previously mentioned in this paper, the upkeep of this form of roofing compares most favorably with every other form. As has been stated, leaks can be easily found, permanently repaired and at a minimum expense. It is waterproof, verminproof and does not become watersoaked, thus preventing an increased load on the superstructure. It will stand more abuse, greater extremes of temperature. It permits of remodeling, additions, and even fire does not destroy its utility.

Long Life and Durability: The only just criticism offered against a metallic roof is its lack of durability. No defense can hide the fact that many metallic roofs, made of steel, have proved a dismal failure, because of their rapid deterioration.

However, a careful review of the history of metal roofing, develops the fact that roofs made fifty and sixty years ago, did not possess this fault. On the contrary, many of these roofs are in service today and are still in good condition. Further investigation into the quality of metal used, proves that they were made from iron.

Some attempt to explain this phenomenon by calling attention to the coating applied, and claiming that the life of a roof depends upon the coating and not upon the base metal. If this is true, why do some galvanized, painted and tin roofs of today

deteriorate so quickly, while these old iron roofs, sometimes on the same building, continue to withstand the ravages of time? One might surmise that the coating of today is inferior, but old experienced coaters say not.

There is just one sane conclusion to be reached, and it is that the durability and long life of metallic roofing depends essentially upon its being made of a base metal free from those impurities which accelerate corrosion. The Electrolytic Theory of Corrosion is generally accepted, and the impurities which hasten decay must be eliminated, if long life and durability are to be attained. Having obtained the best possible base metal, it is necessary that it be coated with the best protective coating obtainable.

The question has been asked, "If the base metal is so good, why coat it at all?" The same question might be applied to other material, by asking, "Why coat a cedar fence-post when placing it in the ground?" the answer is obvious. But, if you paint a poplar post, it would hardly follow that this post will last as long as a cedar post receiving the same protection. Nor does it follow that coated steel, full of impurities the natural accelerators of corrosion, will have the life of a coated pure iron,made to resist corrosion to the greatest possible degree.

Old fashioned pure iron roofs were uniformly reliable. This fact has brought forth a modern pure iron, purer than the old fashioned iron, and although it has been in service only approximately five years, the intense and universal satisfaction it is giving in places where steel failed under the same conditions, is quickly overcoming the one criticism of metallic roofing and eliminating entirely the only unsatisfactory feature.

This pure iron can be made in larger units and consequently at a lower cost than the well made old fashioned irons and because of this fact, it is within the means of all at costs very little higher than steel.

A brief summary why this pure iron possesses the required durability, is as follows:

The chain from the Newburyport Bridge across the Merrimac River, when examined under the microscope shows the well known ferrite structure almost free from slag. The oxygen

content is but slightly higher than pure iron. The high purity and comparative freedom from slag, and the hundred years' service of this chain, proves that the purer the metal the better it will resist corrosion.

According to available records, the Newburyport Bridge had not been painted for seventy years, and even if it had been frequently painted we should expect the paint to wear very rapidly where the links joined, due to the expansion and contraction, as well as the vibration from traffic.

The density, or specific gravity, of iron has considerable influence upon the rate of corrosion; the more porous the material the more rapidly will corrosion proceed and the deeper and more destructive will it be. As first discovered by Kalischer,[1] metals conduct electricity better when their structure is crystalline. Increased conductivity implies better resistance to corrosion. Pure iron has 50 percent higher conductivity than average steel.

The consumer is often unable to judge which grade of material will give him the best service. There are many different grades of iron and steel on the market, such as puddled iron, piled iron, ingot iron, acid and basic bessemer and acid and basic open-hearth, and in addition, the process of manufacture of the same kind of metal, varies at different furnaces.

If the consumer gives an iron of known purity a practical test and in future years desires to secure the same material, he will know exactly the kind of material that has given him satisfaction.

Protective Coatings: All iron roofing should be galvanized or painted. It has been found that pure iron dissolves in molten spelter about one-third as rapidly as steel, consequently the zinc does not become contaminated with as much dissolved iron.

That purity of spelter is of great importance from a corrosion standpoint has been proved, and we have made careful tests of the galvanized coating on pure iron, and find that it resists the action of sal ammoniac, ammonia, dilute hydrochloric acid, and caustic potash or soda better than the coating on steel. The most important point, however, is that spelter on pure iron

[1] Corrosion of Iron and Steel, A. Sang, p. 43.

is from 200 to 400 percent more resistant to the action of boiling water than the spelter on steel.

In the process of manufacture of pure iron, highly oxidizing influences are required in order to eliminate the impurities which exert a marked influence upon the physical properties of zinc, as well as upon its rust-resisting properties. The influence of constituents usually unlooked for in ordinary chemical analysis, such as oxygen, hydrogen and nitrogen, is not fully understood. We should expect, however, that iron or steel, high in oxygen, will corrode rapidly, due to the depolarizing effects of oxygen.

The Effect of Manganese: Numerous investigators have studied the effect of manganese upon the corrosion of steel. Siemens[2] believes that the presence of manganese in steel increases the readiness with which it corrodes. Snelus[3] ascribes the pitting in steel to the irregular distribution of manganese in the metal. Turner[4] has observed that certain samples of manganese steel rust more readily than any other variety in the collection of specimens at the University of Birmingham, while it is well-known that rich ferro-manganese, when exposed to moist air, oxidizes with extreme rapidity. Dudley[5] discovered some years ago that segregated manganese formed centers of corrosion, and it is a generally accepted fact that steels high in manganese are peculiarly liable to oxidation.

Cushman[6] has carried on some careful investigations on the effect of manganese in steel, from which we note the following: "From the standpoint of the electrolytic theory, there are several reasons why the presence of manganese in steel should invite corrosion. Manganese decreases the electrical conductivity of iron, and as the percentage of manganese, starting from zero, rises, the electrical resistance increases up to a certain specific maximum. It will be seen that if the presence of manganese in iron raises the electrical resistance, any variation in the distribution of the manganese means that there will not be a con-

[2] Inst. Journal, 1878, Vol. I. p. 44.
[3] Inst. Journal, 1881, Vol. I, p. 66.
[4] The Metallurgy of Iron, T. Turner, p. 421.
[5] Corrosion of Iron and Steel, A. Sang, p. 84.
[6] Corrosion and Preservation of Iron and Steel, p. 78.

stant electrical conductivity throughout its mass, or on any given surface. There is abundant evidence to show that manganese associates itself, to a considerable extent, with sulphur, when both these impurities are present in steel. ([7]) That manganese sulphide shows a difference of electrical potential against iron is also well known.''

These theoretical reasons which indicate that manganese should stimulate corrosion of steel, provided it is not homogeneously distributed in the iron, appear to be justified by a number of reliable observers, among whom may be mentioned: Dudley[7], Drown[7], Abel[8], Raynolds[8]. Huntley[9] deals with the corrosion of boiler steel, and gives details of a case of pitting in a boiler: ''Each pit was found to be the center of a blister, and the blister contained a slightly acid solution of ferrous sulphate, while the boiler water was alkaline with caustic soda. The solid matter in the envelope of the blister, which consisted of a mixture of iron oxide, acted as a semi-permeable membrane, keeping apart the ferrous sulphate within and the caustic soda outside the blister. The theory advanced is, that the particles of manganese sulphide segregated in the steel, were oxidized by the oxygen dissolved in the boiler water to sulphuric acid and an oxide of manganese, the acid then acting locally on the surface of the boiler plate in the vicinity of the particles of sulphide of manganese. Manganese also increases the occlusion of gases in steel. It is also known to fix oxygen on certain compounds, and that even the solid salts at suitable temperatures hasten the oxidation of many substances. The metal itself will precipitate iron from its solutions, and it is reasonable to infer that with iron going into solution in the presence of oxygen, if there is any manganese present, it will aid its precipitation as an oxide.''

Stoughton[10] on the corrosion of iron and steel has the following to say: ''In short, manganese is only one, although perhaps one of the worst of the evils we have to contend with. We should expect to find that the most resistant metal would be the one which was the most homogeneous in composition, and be-

[7] American Society for Testing Materials, 1908, Vol. VIII. p. 74.

[8] Proceedings Inst. C. E., 1881.

[9] Journal Soc. Chem. Ind., 28, pp. 339, 340.

[10] Engineering Magazine, July 1911.

cause the less the amount of impurity, the less the opportunity for an uneven distribution of it. We should expect that the purer the metal the more resistant it will prove to be. Both of these theories are borne out by the facts as we know them, and it has been found good practice to reduce all impurities—not only manganese, but sulphur, phosphorus, silicon, carbon, and also gases which may occur with the metal, occluded in it, or separated in the form of blow-holes. It will therefore be readily understood that any irregularity in the composition of the metal which produces a difference in potential between two parts, no matter how close together, will increase the rate of corrosion, and this, no doubt, is one of the important reasons why metal charged with blow-holes or occluded gases, or in which the impurities are segregated, has rusted faster than better made material.

American ingot iron, especially, if the manufacturers of it have succeeded in also avoiding blow-holes, oxides and slag, is a very advantageous feature, and should recommend it to users on theoretical grounds at least.''

Influence of Copper; The addition of copper to ordinary steel has the property of retarding the solution of the steel in sulphuric acid. Copper is insoluble in dilute sulphuric acid and exerts a restraining influence upon the solubility in sulphuric acid of either iron or steel.

Natural Corrosion of Copper Steel: Comparisons have been made between copper and non-copper steels by Stead and Wigham[11], who made tests on copper steel by placing samples in the Middlesborough River. While the results are somewhat confusing, the steel containing the highest percentage of manganese and sulphur showed the greatest loss, but this sample incidentally contained the lowest percentage of copper, while another steel, containing only a trace of copper showed less loss under the same conditions than the steel containing almost one percent of copper. Another fact, very noticeable in this test, is that the steel containing the lowest total impurities (excepting copper) showed the lowest loss.

Howe[12] states that some bessemer steel contains a high per-

[11] Iron and Steel Institute, 1901, Vol. II, p. 135.
[12] Metallurgy of Steel, p. 83.

centage of copper while Campbell[13] has shown that most of the bessemer steels recorded in his book contain from 0.30 to 0.50 percent copper.

The careful experiments conducted at Atlantic City show that bessemer steel sheets corrode very quickly and invariably with a peculiar form of corrosion, to which Mallet[14] gives the name of "tubercular corrosion", which he states is due to irregularity in the composition of the original metal. "The result is the formation of mounds of rust, with pitting of the metal underneath. This form of corrosion is not infrequently met with in tubes, boiler and ship plates, and other ironwork, and is usually very rapid in its destructive action."

If bessemer steel invariably contains copper, as has been noted, and if it corrodes in this rapid tubercular manner, the presence of copper did not retard natural corrosion, while it may have retarded acid corrosion. Lang states that we should expect the presence of copper in steel to accelerate corrosion due to its depolarizing effect.

I have endeavored to show the harmful effect of impurities from a corrosion standpoint, and I have shown that the presence of slag is not an indication of resistance to corrosion, as the Newburyport Bridge chain, after one hundred years' service, is found to be almost free from slag, and of almost the same composition as pure iron, made in open-hearth furnaces.

I have also shown the influence of copper, manganese and gases, and will now compare the analysis of pure iron and the chain from the Newburyport Bridge.

	Newburyport Chain	*American Ingot Iron*
Carbon	.0500	.0150
Manganese	.0050	.0100
Silicon	.0190	.0040
Sulphur	.0070	.0200
Phosphorus	.0320	.0030
Copper	.0070	.0500
Oxygen	.0580	.0270
Nitrogen	.0033	.0035
Hydrogen	.0005	.0006
	.1818	.1331

[13] Metallurgy of Iron and Steel, p. 358.

[14] Metallurgy of Iron, p. 418.

Having thus shown the high purity of both metals adds more evidence to the correctness of the electrolytic theory of corrosion, and shows the necessity of removing those elements from iron which differ from it electro-chemically, which is being done in the manufacture of pure iron.

Mr. E. O. Newsome:* I assure you I had no knowledge that I was going to be called on this evening, so I am utterly unprepared. Perhaps if I give you a very brief history of the way we started in to protect sheet steel, it would enlighten you somewhat.

The material which we manufacture is known as Asbestos Protected Metal. Perhaps it would be better in one sense to call it asphalt protected metal, in that asphalt is the basis of the protection. We use a sheet of steel, bessemer generally, or open-hearth, and pass it through a bath of asphalt. The asphalt compound is naturally a secret mixture, which is composed of asphalt and fluxes so mixed that it has a melting point sufficiently low to make the asphalt flexible at zero degrees fahrenheit, yet sufficiently high to prevent melting under a temperature of 250 deg. fahr. This sheet is passed through the asphalt bath and as it emerges from the asphalt bath coated, it goes up between two layers of asbestos felt or paper. It is there squeezed, the two sheets of paper or felt adhere to the steel; and the product piled up and allowed to cool. The amount of asphalt compound that goes on is determined by the pressure rolls, and the heat of the asphalt. It is next taken and formed into practically any shape that galvanized iron can be formed. We do not solder it, simply because it is impossible to solder the material after it is asphalted. After forming it goes through another process, which we call Duck-back. You all know the ordinary surface of asbestos is soft. It is not water-proof, because it generally contains seven percent of water by absorption sometimes as high as fourteen, has four to six percent water of crystallization, and it connot be anything but soft and absorbent. For these reasons we put it through the Duck-back process. This Duck-back is a mixture which renders asbestos waterproof, and at the same time makes the surface hard, so that

*Treasurer, American Protected Metal Company, Beaver Falls, Pa.

it will not become abraded during the application to a building or by walking upon it afterwards.

The theory upon which asbestos protected metal is now made is this: The asphalt is put upon the sheet to prevent the entry of moisture and oxygen. A sheet which is thoroughly sealed from the action of moisture and oxygen should, if our theories are at all correct, and if the general theory of the protection of metal is correct, be absolutely permanent. If the water and the oxygen or moisture is kept out, then we should have no change. Asbestos protected metal, by the action of the asphalt, seals the sheet up entirely. It laps over the edges, it laps over both ends. Although the process is continuous, it is so arranged that both ends are protected. That being so, the asphalt is the thing to be considered. Is the asphalt permanent? We all know asphalt is not permanent, it will dissolve; the actinic rays of the sun may take the life out of it, destroying the oils. Put a sheet of asphalt-coated steel outdoors, and in three or four weeks, perhaps four months, it will undergo what we call "alligatoring"; that is, it will seem as if the skin of asphalt had contracted, and it will look exactly as an alligator's skin, little islands of asphalt and little rivers of bare steel. Now, asbestos protected metal will not undergo that, for several reasons. In the first place, we keep the water out by a water-proof coating of asbestos. In the next place, and the thing that is really essential, is the keeping of the sun's rays out. We do that by an opaque substance, asbestos, which is impenetrable to the rays of the sun. They do not get through and chemically act on the asphalt. Then in the next place, to prevent the evaporation, we have in the asbestos a coating which is composed of a considerable amount of water. It is well known that oil will not pass through water and will not evaporate through water. We cover this asphalt with a sheet of asbestos, which normally contains from seven to fourteen percent of water of its own, that is, by absorption, and four percent water of crystallization; hence there are the three things which prevent the asphalt from evaporating or changing: The asbestos waterproof preventing the water getting at it, the opaque as-

bestos preventing the sun acting upon it, and the moisture of the asbestos preventing the oils getting out. While, of course, that theoretically makes a perfect sheet, we do not deny that some change will take place, undoubtedly some does; but for a light building material of sufficient strength, and answering in every way the same uses as corrugated galvanized iron, we believe that this product is suitable for severe conditions—not simply conditions such as we find around Pittsburgh, but for extremely severe conditions where there is sulphur and other deleterious substances present. We do not say that it can be used for cans for carrying sulphuric acid, or anything of that kind; but we do know, from an experience covering a period of six years, that asbestos covered metal will hold up in a sulphuric acid plant; and I do not think that anybody can conceive of a harder proposition than where there is constantly present dilute sulphuric acid in the air. We have at certain plants in Massachusetts, where in our infant days we started making asbestos protected metal, some very thin material. In those days we did not know as much as we do now, but that material is still in use on plants where hydrochloric acid is made.

Mr. J. O. Handy:* Referring to "Monel" metal which has come into very extended use. This is a product of the high-grade nickel copper matte made by the Canadian Copper Company, at Sudbury, Ontario. Mr. Monel discovered that it would be less expensive if instead of reducing the matte into its constituent metals, copper and nickel, they should reduce them both at once and make what has been called a natural alloy of copper and nickel. Monel metal is being manufactured into sheets, tubes, rods, wire and a great many other forms. We know that steels containing large percentages of nickel when made into boiler tubes, resist corrosion better than any other metals which have been used for the purpose. Monel metal has been used for propellers of ocean-going steamships and for many other purposes where its water and weather resisting properties play important parts. That is all I can say now about Monel metal. I can say a little about copper as a roofing material.

*Chief Chemist, Pittsburgh Testing Laboratory, Pittsburgh.

COMPOSITE COPPER STEEL ROOFING

The gentlemen who have already spoken have said it would be very desirable if these metallic roofing materials could be used without being painted. But as it is, their metallic roofings do a certain part of the work and the rest is done by the paint or the asphalt, as you have heard. Now, copper is the one common metal which occurs in the native or metallic state, in very large quantities in Michigan and elsewhere. This, of course, is the best proof we could have of the weather withstanding proerties of the metal. Some of the ancient copper implements of prehistoric times used by early races have come down to us, corroded slightly to be sure, but still largely metallic. As your chairman has said, metallic copper is unquestionably a durable metal to use for roofs, gutters or rain conductors. It is used on houses where expense permits. It would be very simple if we could make copper covered steel or iron, as we make terne roofing plates or galvanized sheet iron, or steel, by dipping steel sheets into melted copper, but so far this has not been done to any extent. That is mainly due to the high melting point of copper which is 1980 deg. fahr. against 786 deg. fahr. for zinc, 621 deg. fahr. for lead and 450 deg. fahr. for tin. It is difficult to say the least, to dip sheets in melted copper and take them out and preserve their good qualities, because at the high temperature the copper would readily oxidize and become unsightly. There is, however, another method, the *welding* together of copper and steel. That has been done, and done successfully, and I can show you an example of it. This (indicating) is a sheet of steel 4½ ft. by 10 in. by 20 gauge with copper welded on one side. The steel does not show anywhere through the copper. This other sheet is simply one 15 inches in width of the same material, steel on one side and copper on the other. It can be made with copper on both sides. Welding copper upon steel has this distinction from the process of galvanizing, or coating with tin or an alloy of tin and lead. Those processes depend on the formation of an alloy of the coating metal and the iron at the surface of the steel. This composite copper-steel does not have such an alloy, because it is made at a temperature below the melting point of either of the constituents. It may

be made, under the right conditions, to avoid flaws on oxidation of either metal. I personally think a metal of this kind has a great future, because, as you know, copper does not require any paint to protect it from air or water.

MR. J. A. MCEWEN:* The true value of any roofing material is realized only when it is used under conditions and circumstances to which it is especially adapted.

Metallic roofing has a very valuable place among roofing materials, but should be adopted only under conditions suitable to its use. Some of these conditions may be designated as follows:

First Cost: There is no roofing of a self-supporting and substantial character which can be furnished and applied as cheaply as the corrugated iron roof.

Permanency: If the material is of the best quality and is cared for properly it deserves to be ranked with the permanent and substantial classes of roofing materials.

Fire-Proof: While not indestructible by fire it belongs to the fireproof class of materials.

Strength: By corrugating the material a self-supporting roof is produced, and the roof purlins can be spaced up to six feet apart.

Lightness: No roofing material is made of equal strength with as little weight.

Rigidity: If well put on it adds very much to the stiffness of a building.

There are also conditions under which corrugated iron should not be used as follows:

Weather Proof: It is not air tight, and when buildings are to be heated it should not be used.

Anti-Condensation: Where condensation on the underside of roofing is undesirable, corrugated iron should not be used alone.

Monolithic Construction: When monolithic buildings of the most permanent character are desired, corrugated iron is not suitable.

*Manager, Pittsburgh Bridge & Iron Works, Pittsburgh.

Pitch of Roof: Corrugated iron should not be used on roofs of less than one-fifth pitch.

Destructive Fumes: Where there are fumes generated destructive to iron, metallic roofing should not be used.

KIND OF METALLIC ROOFING

Metallic roofing can be applied in the form of shingles, or in sheets with standing seams, but in this form must be supported on wood sheeting. This is usually applied only on dwellings.

The most practical form of metallic roofing is in the form of corrugated iron, the corrugations producing a very strong and rigid material.

The quality of the iron or steel used in the manufacture has a great deal to do with the longevity of the roof. There are three primary groups of materials used in corrugated iron roofing: black steel, muck bar iron, and galvanized material.

The common black steel has very poor rust resisting qualities, and unless galvanized or protected in some other substantial manner, we would not recommend its use except for the very cheapest and temporary construction.

Muck bar iron costs from 40 to 50 percent more than steel, but its permanency recommends it as the cheapest roofing in the long run.

There are a number of other kinds of iron sheets on the market, such as "Ingot Iron", "Newport", "Toucan Metal", etc., for which great claims are made. These claims may be correct for the particular tests specified, but the writer's opinion is that the only test which will fully demonstrate their real value is the test of time. The sulphuric acid test, of which we hear so much, is seldom if ever encountered in actual practice. The metallurgist and the chemist seem to be unable as yet to determine what chemical combinations produce iron or steel of the most lasting qualities. As far as actual practice and experience have demonstrated there seems to be no more permanent materials than the old-fashioned Muck Bar Iron.

PRESERVATION

As in the line of structural steel, so in that of metallic roofing, the most vexing problem is the preservation of the steel. The most permanent results along this line have been obtained by the galvanizing process. This process, however, adds from 30 to 40 percent to the first cost of the material. If this is done in a proper manner and with proper materials we believe it is a profitable investment. Galvanizing is usually done before the corrugating is done, and here we think a serious mistake is made, for, with poor materials and careless corrugating, the galvanizing is more or less damaged and tends to crack, curl up, and flake off. The ridges should be easy curves and not made sharp in order not to break the galvanizing, and the galvanizing material should be of an elastic character.

All kinds of metallic roofing should be painted from time to time, even the galvanized material should be painted as soon as signs of rust appear. We will not attempt to recommend the best paint to be used, as this problem seems to be very far from its final solution.

There are some new things being put on the market, such as asbestos protected metal, aluminum coated, etc., which seem to be developing along practical lines. The failures, however, of some of the first products have seriously handicapped the sale of what may be really good articles.

Mr. V. R. Covell:† Is there a material difference in the thickness of the coatings of terne plates or galvanized iron, and, if so, what regulates this thickness?

Mr. D. M. Buck: The coating in the best grades of tin plate is about the same thickness as the coating on regular galvanized sheets.

Mr. V. R. Covell: My question is, is there a difference in terne plates and galvanized iron sheets, one as against another? Does the thickness of the coating vary?

Mr. D. M. Buck: If you refer to the uniformity of the coating from sheet to sheet, there is always a slight variation in

†Deputy County Engineer, Court House, Pittsburgh.

thickness, since under the present knowledge of the art, it is impossible for anyone to manufacture a sheet with a perfectly uniform coating.

Mr. V. R. Covell: Is the durability of these sheets due to the thickness of the coating? Do some manufacturers make thinner coatings than others, and what regulates the thickness? Can it be varied at will?

Mr. D. M. Buck: Yes, the thickness of the coating can be varied at will, and undoubtedly dishonest manufacturers have put on the market supposedly high grade plate which was much more thinly coated than it was represented to be. On the other hand, reputable manufacturers sell several different grades of terne plates, increasing in price with the thickness of the coating.

Mr. W. G. Wilkins:* An old manufacturer told me that about twenty years ago, he was building a corrugated iron-covered building. He specified that the black sheets should be dipped in linseed oil before they were put on. He said they ran short about one square of covering the sides of the building, and took the ordinary black corrugated iron and placed it on the building. He said the sheets that had been dipped in the linseed oil, while they were hot, were still on that building, and the square that had not been dipped rusted out inside of two years. That may be an interesting fact. The linseed oil seemed to have just as good an effect, when properly applied, as the terne or galvanizing.

Mr. J. A. Ferguson:* There is another point in the application of all these different kinds of roofing that I have not noticed has been discussed tonight, and that is the fastenings. It occurred to me that where the rivets were put through to fasten the clips on, was a vital point. I saw an old mill building right alongside of where we were working, where the rust seemed to attack the plates next to the rivets, and around them, and the rivets would rattle loose, and that would destroy the usefulness of the plates. Can anyone explain how that can be avoided?

*Consulting Engineer, W. G. Wilkins Company, Pittsburgh.
*Assistant Engineer, Bureau of Construction, City of Pittsburgh.

Dr. K. F. Stahl:† We have quite a number of buildings of corrugated iron. For some years we have fastened it by punching two holes, 2½ inches apart (the width of the corrugations), through which we run staples made from No. 10 annealed wire. The legs of the staple are bent around the supporting angle. This has proved to be sufficient hold. For roofs the holes must be punched in the ridge of the corrugations to avoid leaks. If the roof has to be absolutely water tight the holes may be puttied up. This method is simplier than the one usually employed of holding the sheets with riveted strips and the fastening lasts as long as the sheet because it does not cause rust like the rivets do.

Dr. J. A. Schaeffer:‡ About three years ago a fence was erected at the Technical Schools, on which were tried out various coatings on galvanized wire and ungalvanized wire by the American Society for Testing Materials, in connection with the American Steel & Wire Company. That fence now is at the most interesting stage of its development. During the past year some of the strands of that fence have gone to pieces. I want to extend an invitation to any of the members of the Society to come to the Schools and look at that fence, for I think every one could get some good practical points from it concerning the wearing of paint coatings when applied to galvanized iron or iron itself. There were put on that fence galvanized iron of various kinds, Sherardized wire, various carbon blacks, paints, green and yellow paints, and all in all I think you would find a very interesting hour's study of that fence, as far as coatings go.

Mr. A. Stucki:* Mr. McEwen, said something about painting galvanized sheets as soon as the rust started to show. Is that proper? Should we not paint the sheets before corrosion sets in? I have heard that paint does not stick well to galvanized sheets. Possibly that is the reason Mr. McEwen made the remark.

Mr. J. A. McEwen: In answer to that question, perhaps

†Superintendent, General Chemical Company of Pennsylvania, Pittsburgh.
‡Chemist, Picher Lead Company, Joplin, Mo.
*Consulting Engineer, Oliver Bldg., Pittsburgh.

I did not state it in the proper fashion; but some specifications call for galvanized iron to be painted several months after it is put on. The idea of the galvanizing is of course to protect the steel or iron without painting. The painting is a further protection, and my idea of that is that when the galvanizing begins to show signs of not fulfilling its duty, then we must have recourse to the paint, because we cannot galvanize again after the sheets are on the building.

Mr. L. C. Moore:† The gentleman that spoke regarding the asbestos and the asphalt—Is the metal cleaned before the asphalt is applied?

Mr. E. O. Newsome: The material used is one pass cold rolled bessemer or open hearth annealed sheets. The amount of scale on this sheet, as you know, is extremely slight. In order to make sure that the asphalt gets a grip on the metal, pains are taken to see that the sheets are absolutely free from rust and grease. The rust itself, by reason of the finely powdered condition of the iron oxide present, would prevent the asphalt getting a firm hold, and, as there is also a large percentage of moisture present, this in itself would prevent adhesion. As a precaution against the moisture which ordinarily exists in and upon the surface of the metal, the sheets have a preliminary heating before entering the asphalt bath. Sheets which by any accident have grease upon them are carefully cleansed with a grease removing substance.

Mr. L. C. Moore: I have had some little experience during twenty-five years galvanizing metals, and it leads up to this: If you clean your metal, and then paint it, and keep it painted as well as you have to keep your galvanized sheets painted, you will get along just as well without your galvanized metal as a base.

Mr. W. G. Wilkins: I think the gentleman is right to a certain extent. I have had some experience with ordinary galvanized iron, corrugated iron, commercial corrugated iron, and as you all know, unless you know what you are getting, you generally get corrugated steel. Now, I have had corrugated steel

†Consulting Engineer, Stevenson Bldg., Pittsburgh.

and corrugated iron both, and I have had them well painted, and I have noticed where the sheets on the sides of the building come down to the ground, where the water strikes the gutters, that it is only a short time until the corrugated steel is full of holes, while the corrugated iron will last a great many years. And I think what the gentleman said who read the paper is true, that the material which you get has a good deal to do with its lasting qualities.

Mr. J. O. Handy: If there were a paint manufacturer here and he were inclined to be a scoffer, he would say, "Gentlemen, all I want is some steel for a stiffener for my paint; my paint does the work." But speaking seriously, you listened just now to Dr. Schaeffer, of the Technical Schools, and his invitation to inspect the painted test fences I think we ought to accept. A demonstration of that kind speaks for itself.

Mr. D. M. Buck: From statements made by one of the speakers this evening, a misunderstanding might easily be had by some of those present relative to the condition of the plates on the test fence at Atlantic City. I have had occasion to examine these fences every few months since they were erected, and the "tubercular condition" is not present generally on the steel sheets, as might be inferred from Mr. Aupperle's statements, but is only present on one of the Bessemer Sheets, and on that one is confined to a region near the ground. The three or four other Bessemer Sheets and all of the Open Hearth Sheets are in at least good condition of preservation as the socalled "pure iron."

Now, I have no quarrel with theory. It has its place and is very valuable at times, especially in preliminary and development work. But I do think that in comparing materials of construction to determine relative lasting qualities, no theories or no accelerated tests are of as much value as the actual tests of time and service.

It has been my privilege during the past few years to make a great many of these tests under actual service conditions, comparing regular Open Hearth and Bessemer steels with some of the so-called "pure irons". I have taken sheets from a great

many different heats in order to get as nearly as possible the average product of the several processes of manufacture, and the results of these tests have proved to my satisfaction that there is on the average very little difference in the wearing properties of these three materials in their resistance to corrosion. Under no conditions of exposure have I found any material superiority for the so-called "pure irons", and in some instances they have proved very dicidedly inferior.

Mr. L. C. Moore: I want to say one thing more about galvanizing. The wire from which the supporting cables were made in the first Brooklyn Bridge was galvanized. The wire in the Manhattan Bridge was not galvanized. Now, there is going to be a very interesting result in the course of a few years. The first Brooklyn bridge, we all know, has been built some eighteen or twenty years, and, so far as we know, it is still carrying its load safely.

Mr. Harry Lewis:* There is one point that has not been brought out very prominently, in regard to these metal roof coverings, and that is the element of lap. We cannot make a roof of a continuous sheet, and it would not be a very good roof if we could make it so, because the expansion would probably pull it to pieces, if of any size. So we have to lap the sheets. We also have the contact between the sheet and the purlin. Now, those are surfaces which, after you get your roof on, are inaccessible to any paint treatment, and these are the places which from my experience, have been very fruitful sources of trouble. I am inclined to think that the galvanizing, or terne coating, or whatever alloy surface of corrosion-resisting metal is put on, is probably of more value in this inaccessible portion than it is in the part of the roof that can be cleaned and painted. The exposed surface inside and out can be taken care of with paint; but these other portions, which are always subject to condensation and to the holding of water by capillarity, when you have your roof on, they are covered up once for all. The contact between the roof sheets and the purlins has been one of the most fruitful sources of corrosion I have noticed in old roofs.

*Consulting Engineer, 336 Fourth Ave., Pittsburgh.

Mr. J. O. Handy: I would like to ask Mr. Buck whether, if he had any customers who would pay the price, he could not make a terne roof which would not need any paint, the coating being made thick enough so that its water-resisting properties would protect the steel underneath.

Mr. D. M. Buck: We do make such a sheet. But it is still true that any additional protection that is given to any building material gives it additional life. In my opinion it is not good practice to use any coated iron or steel sheet without painting it. As is well known to the user of sheets, paint will not adhere well to new galvanized sheets, and it is, therefore, advisable to expose them unpainted for some time so that the surface may be slightly roughened by the formation of basic zinc carbonate by the action of the weather, but I firmly believe that the sheets should be painted with a good paint as soon as that point has been reached.

Mr. V. R. Covell: In the course of a recent conversation, a sheet metal contractor expressed regret because the architect on a certain building had specified ordinary tin instead of imported charcoal tin, or terne plate, with a charcoal iron base. Is this as important as the quality and thickness of the coating? How can the layman satisfy himself that he is getting a certain thicknes of coating?

Mr. D. M. Buck: The only sure way to determine the thickness of the coating is by chemical analysis. One experienced in the handling of sheets can tell approximately the thickness of the coating by certain peculiarities in the appearance of the surface, but to the layman this is impossible, and he should purchase his sheets from reputable dealers and manufacturers, when he can be certain that no misrepresentation will be made.

Mr. W. G. Wilkins: I am sorry somebody has not brought out the question of the paint used on the steel roof. I hoped to get some light on that question. A short time ago, a manufacturer of tin plate told me he had had his chemists for some time making experiments, to discover the best paint to put on tin, for roofing purposes; he said that they discovered that a

certain kind of mineral paint—I won't mention the name, because he gave it to me in secrecy—was the worst thing that could be put on, for the reason that the paint itself had so much acid in it, that it was not long until it ate clear through the tin coating.

Dr. J. A. Schaeffer: I believe I can give some information on that. The fence that was put up at the Carnegie Technical Schools contained several strands of galvanized wire. This galvanized wire fence has practically gone to pieces. Now, when that galvanized iron was painted with different paints, various conditions were found at the end of a few years. It showed the utter fallacy of painting galvanized wire or ungalvanized wire with graphite paint. All graphite coatings have practically gone to pieces. The paints which contained a small percentage of willow charcoal have stood up much better than the graphite paints, for the reason, I suppose, that there is a small amount of alkali present which would tend to prevent corrosion. One part of the fence was coated with a zinc chromate paint. That fence is just about the same as when erected. The coating can be scraped off showing the wire in about the same condition as when it was put up. The fences painted with chrome green pigments, show some corrosion, but not as much as the ones painted with carbon black paint.

A paint was put on a fence which was mainly an iron oxide. It is a prepared paint which consists of a high grade of iron oxide, together with a small percentage of zinc chromate; that fence is practically the same as when it was first erected. The Sherardized wire, while it has held up a little better than the galvanized wire, shows rapid signs of corrosion.

Mr. W. G. Wilkins: Did you try red lead?

Dr. J. A. Schaeffer: Red lead was not tried on the fence at the Schools. It has held up very well on the Atlantic City test fence. The best paint I believe that has been found, although its price prevents its being used, is American vermilion, a basic lead chromate.

Mr. J. A. Aupperle: I would like to ask how the rate of corrosion was determined, also if only one of these sheets did show the tubercular corrosion, how is the consumer to know whether he is going to get the material that will form that tubercular corrosion, or some material that will not.

Mr. D. M. Buck: Mr. Chairman, wherever possible in my experience, the sheets have been weighed before exposure.

Mr. J. A. Aupperle: I am referring to the Atlantic City tests.

Mr. D. M. Buck: That must be solely by inspection, as far as I know.

Mr. J. A. Aupperle: Now, as Mr. Buck admits that he did not clean and weigh the samples exposed at Atlantic City, but that he determined the rate of corrosion by looking at them, I should like to ask him whether he draws his conclusions from the color of the rust, from its sponginess, from grain size of rust, or from the tubercular form of corrosion. American ingot iron on this test fence will be found to have a fine grain, dense, closely adhering form of rust and to be absolutely free from tubercules.

Mr. D. M. Buck: My opinion on the plates on the Atlantic City test fence is based on a careful inspection of them on the fence. To be absolutely certain of the condition of the surface of the sheets under the rust, it would be necessary to take them down and clean them. In my own tests, results were obtained not alone by inspection but also by actually weighing the sheets before and after exposure.

Mr. Edward Godfrey:* Tar paint does not receive the attention it should. One thing against it is that it is cheap. Another thing is that it is not made by paint manufacturers. When it is mentioned, they hold up their hands in horror. It is made out of tar, Portland cement and kerosene. They don't manufacture any of these. Naturally it doesn't interest them. But it has been found to be very good on thin tin roofs. I have used it myself, that is, I have used a paint

*Structural Engineer, Robert W. Hunt & Co., Pittsburgh.

that I presume is the same thing. It is called American Cold Japan and I know it is a tar paint. I know that engineers have used with success a mixture they prepared themselves, and which only costs ten or fifteen cents a gallon, tar, cement and kerosene. This paint can be used not only to protect the roof, but also to mend it. By the use of a little patch of canton flannel, a leak in the roof can be sealed up without any difficulty, and it will stay there for years, as good as a patch put on with tin, probably better, because there is no application of acid to hurt the tin, just apply the paint and put on the patch and then paint it again. I think that a test of this kind of paint would be very useful. It is used by the Army engineers, and the structural engineer of the New York Shipbuilding Company regularly uses this kind of paint on tin roofs, and mends them in this manner.

Mr. L. F. W. Hildner:* I would like to say a word about that kind of paint. I don't know definitely whether it is the same paint that Mr. Godfrey is talking about, but we have had recently some experience with a paint that while it costs only about ten cents a gallon, cost about four times as much as ordinary paint to put on. It made the men nearly blind and took the skin off their faces and hands. I think there ought to be a law passed against even suggesting its use. I do not know that it was your paint. In the first place, the paint was too thick to stir, and it was too thick to brush on. The men would get some on after awhile, but when the metal became hot in the sun the paint would drop off.

Mr. Godfrey told us about patching. Mr. Todd of the Crucible Steel Company is here. I do not know whether he personally has any experience putting muslin over corrugated iron at their works.

Mr. J. W. Todd: We patch once in awhile as a last resort. We do not consider muslin a roofing material. Where small holes show up in roofing, we put a muslin patch over the holes and paint over the muslin.

*Chief Engineer, Pittsburgh Bridge & Iron Works, Rochester, Pa.

Mr. L. F. W. Hildner: Mr. Todd, perhaps three or four years ago, I saw in one of your plants where they were coating an entire corrugated steel roof with muslin and painting it over, this was at your Park plant. I would like to find out just for the interests of the Society, just how that worked out. I know it was very popular around here two or three years ago.

Mr. Edward Godfrey: I can say there is no difficulty at all in applying this. It probably would not be the best kind of paint for structural steel, in general, because of its appearance. It "maps," that is, draws up in blocks. It does not draw away from the steel, but it shows shiny streaks. You could not paint over it with another oil paint. Some information on this paint will be found in Engineering News, July-Dec., 1906.

Mr. A. Stucki: What is good for the first coat is not good for the second coat, and vice versa. We had this question discussed thoroughly some years ago before this Society. With the point in view, to determine, how steel can best be protected. I was then thoroughly satisfied in my own mind that for the first coat, an iron oxide paint is the proper thing, while for the second coat it would not be. It adheres well to steel, has certain rust preventing qualities and is very hard. Graphite paint on the other hand is well adapted for the second coat, because it is plastic and does not crack so easily under punishment. For the first coat this paint is not so desirable.

From a commercial point of view, what is the price of asbestos covered roofing sheets compared with steel sheets, in a general way?

Mr. E. O. Newsome: Compared with galvanized iron sheets in the corrugated form, Asbestos Protected Metal runs from 25 to 45 percent higher per square applied to the building. We maintain, and we feel that experience has shown us to be correct, that a longer life justifies the increased first cost. The reason for the higher price of this material is simply that more valuable products are used in its manufacture than are used in the galvanized sheets. There is a greater opportunity

for loss during the manufacture and the process itself is more expensive.

A Visitor: If there are other engineers or chemists present who have inspected that fence at Atlantic City I would be glad to hear further regarding it.

Mr. J. O. Handy: Dr. Schaeffer could talk more in detail about the tests at Atlantic City. One effect which developed at an early stage was the failure of paints containing calcium sulphate or gypsum, which was at one time quite a common addition to red oxide of iron paints, and to some of the white paints. Since that test, it has not been used so extensively. I think Dr. Schaeffer could tell us more about various paints as they behaved down there.

Dr. J. A. Schaeffer: The interesting thing in the Atlantic City fence was the action of corroded white lead. Corroded white lead, as you all know, has been used as a paint pigment for years, and they applied it to the test fence at Atlantic City. They found that corrosion proceeded very rapidly. It was given a rating of 3.7 on a basis of ten, American vermillion, being the best, receiving a rating of ten. That was one of the most notable things in regard to the various standard coatings, as we might call them. The pigments that were best were American vermillion, the chromates, sublimed blue lead and sublimed white lead. The latter pigments received ratings of 9 and 8.8 respectively. They were the best pigments applied to the fence which can compete as paints in a commercial way.

The pigments below eight in the rating as found on the Atlantic City fence are only of little value as first coal pigments.

The article by Mr. Gardner on Paint Protection for Iron and Steel in the Engineering Record of August 26, 1911 discusses the report on the Atlantic City Test fence in detail.

Mr. J. A. Todd: I would like to ask Dr. Schaeffer whether he knows of any tests of so-called tar paint.

Dr. J. A. Schaeffer: I don't think any tests were carried out in the tar paints, as far as I can learn; none that I have ever seen.

MR. J. O. HANDY: I think it would be found that the tar paint should be used only on roofs of low pitch.

MR. V. R. COVELL: A paint, evidently similar to that referred to by Mr. Godfrey, has been used by the Pennsylvania Lines West to protect the steel of bridges from the salt water of refrigerator cars. This has also been used on two county bridges at points specially difficult to protect. The formula used is as follows: 8 parts coal tar, one part Portland cement, and one part kerosene oil, all by volume.

MR. J. W. COGLEY:* Referring to the question asked about protecting rivets driven through coated sheets. An unprotected nail or a rivet penetrating or put through an aluminum coated sheet will not rust off on the exposed surface, but will take on a protective coating from the composition of the aluminum, copper and tin, in our coating material. We have demonstrated this in a great many places where all the fastenings were unprotected, and there is not a sign of rust or corrosion on them. Friday, a week ago, after making an examination of one roof after three years exposure, we failed to find a rusted rivet, but all had taken on a protective coating from the aluminum mixture, and were almost as white as the sheets themselves. The government engineer's architect, Mr. Ashcraft, has given us the privilege of furnishing aluminum coated sheets for several buildings. Today he told me that he recently examined the sheets on the building at Lock No. 2, which were put on some time ago and have never been painted, after a very trying test on account of the dust from nearby furnaces. This red ore dust, thrown out at every slip, settled on the top of the roof and in the gutters sometimes as thick as a quarter of an inch in a week's time. Instructions had been given to the foreman in charge of the Locks to pay particular attention to the aluminum coated sheets, and report the first appearance of rust. The foreman requested Mr. Ashcraft, within the last week, to examine the roof, as it showed signs of rust. After a thorough examination Mr. Ashcraft found that the red ore settling on the roofs had run down and stained the aluminum coated sheets.

*Secretary, Wilder Metal Coating & Mfg. Co., Connellsville, Pa.

It was easily wiped off with a piece of waste, and the nails the gutters were put on with, though unprotected at the time they were put on, had taken on a protective coating from the sheets and showed no signs of rust.

Mr. J. A. McEwen: The question of fastenings was raised here and no definite answer was given to it. I think all users of galvanized iron agree that it ought to be put on with regular clips and riveted instead of being put on with clinch nails. As to the rusting of the sheets around the rivets, that can be overcome by using a copper rivet. At least, a galvanized rivet should be used and riveted on the inside.

Referring again to the galvanizing of corrugated iron, I think it is a mistake to go to the expense of galvanizing the better grades of material. I think that the only place it pays to go to this expense would be on the cheaper grades of material, the steel, for instance, which is equally as strong as the better grades of iron, but needs the additional protection. The galvanizing does not depend, we believe from observation, so much on the thickness of it as the quality of the materials used and the manner in which it is put on. Take a galvanized sheet, bend it sharply, turn it towards the light, and you see little streaks in the galvanizing, indicating that you are breaking the galvanizing. I think a mistake is made by corrugating the iron after it is galvanized. The galvanizing ought to be of such a nature as to sort of flow when the sheets are bent, and not crack and expose the steel.

Mr. J. O. Handy: I think we will have to change the nature of zinc somewhat to eliminate those properties which make it brittle when it is put on as it is. On cooling from a liquid state it crystallizes, and that is what makes it crack as it does upon cold bending or treatment of that kind.

Mr. R. B. Woodworth: The books on roofing published in England and in Germany lay great stress on zinc roofing. To my knowledge, I never heard of a zinc roof put on in the United States. I would like to ask if anyone here ever saw one?

Mr. L. F. W. Hildner: I think the question has not been

fully answered about the unpainted galvanized corrugated iron and steel. I think Mr. Aupperle could answer that. I have understood, that in tropical countries, galvanized steel is used without painting throughout its entire life. These sheets are made in England. We have one experience where a roof has been on five years and unpainted, though this is not in the Pittsburgh District. A good corrugated steel should never be painted.

Mr. J. A. Aupperle: As far as the protection of the galvanized sheet, a very good example of that is shown in the fence at Atlantic City. There the sheets have been exposed under the same conditions for three years, and the cut edges do not show any material corrosion.

Mr. J. M. Fouse: By way of experience as to corrugated roofing, I was in South America a few years ago, and the company I was working for had all their buildings covered with corrugated galvanized roofing. At the time I was there, after ten years of service, all that galvanized roofing was in splendid condition; in fact, there was no sign whatever of rust. I think that roofing was made in Holland.

Mr. J. A. Aupperle: It has been my privilege to examine a piece of galvanized roofing that has been exposed on the Isthmus of Panama ever since the time the French Government started to build the Canal, and that sheet, after all these years of exposure, was in very good condition and had never been painted.

Mr. Edward Godfrey: Mr. Chairman, I think some of the difficulties with pure zinc as roofing are these: It is very hard to solder, on account of the melting point being not much above that of solder and a soldering torch is apt to melt it, also in the large sheets, the expansion and contraction is very great, and it wrinkles up in a roof.

Mr. J. A. Aupperle: I do not think there is much difficulty in soldering galvanized material. There is quite a difference between the melting point of solder, which is somewhere around 200 degrees centigrade, and the spelter, above 400 de-

grees centigrade. So I have never experienced any difficulty in soldering galvanized material.

Mr. Edward Godfrey: I was speaking of pure zinc.

Mr. J. A. Aupperle: There is 200 degrees difference in their respective melting points.

CORRESPONDENCE

Mr. R. B. Woodworth:* I think if these discussions on roofing materials, both metallic and non-metallic,† has not served any other purpose, it has at least called our attention to the importance of the roof covering as an engineering problem. Space and time have not allowed us to do anything more than to get a general idea of the number of entirely satisfactory roofing materials which are at the disposal of the user, and there are a number of other materials which have not been included in the discussion. I think it might be well to refer briefly to the general aspect of the problem, in a way as a summary of our discussion, and at the same time to mention some of these other roofing materials so as to make our discussion more complete.

I take it for granted in the first instance that there is no roof made out of good materials in a workmanlike manner which does not find a satisfactory field for its use. There is no roofing so cheap but that there is a building which it may economically cover ;neither is there any roofing material so dear but that there may be found for it a structure for which alone it is suited from both a physical and economical standpoint, and in the ultimate analysis the problem of the engineer is to decide what particular roof or roofing is best adapted to cover the building under construction, and by best adapted is meant of course that which will most satisfy all the requirements of the case and produce the greatest probable return on the least possible expenditure.

Materials of construction are properly classified and used in accordance with their moments of resistance, and a good roof is that which resists well the forces tending to its destruction.

*Engineer, Carnegie Steel Company, Carnegie Building, Pittsburgh.

†Proceedings Engineers' Society of Western Pennsylvania, 1911, Vol. 27, No. 7.

The best roof is of course that which resists these forces in the highest possible degree and for the longest time, consequently in the choice of roofing materials the elements of chief consideration are:

1. *Watertightness*: High resistance of the roof to penetration of water in either a liquid or a solid condition. It is required that the roof should not only shed water freely under severe rain storms but that it should also give a good account of itself when fine particles of snow are forced against it by driving wind, or again when ice lays upon it with alternate thawing and freezing during the winter months. To satisfy all these conditions not only must the surface of the roof be impervious but the joints must be constructed in such a way at to prevent the failure of the roof at, so to speak, its connections.

2. *Wind Resistance*: While the driving action of the wind may force snow or ice into the roof joints, it may also destroy the roof surface as a whole by its bodily displacement from purlins or rafters or by the disruption of the surface between points of support. To obviate this latter condition minimum thickness of roof covering must be avoided, particularly in the case of such fragile material as glass. The attachment of the roofing to the sheeting must be simple and secure. Other things being equal, a heavy roof is in this direction preferable to a lighter one.

3. *Fire Risk*: Resistance to fire is a requirement which varies somewhat with the character of the building and with its location. Within city fire zones the building laws require that the roof covering shall be fireproof and that slate, tile, metal or other incombustible material must be used. This or a like form of expression appears in the building laws of all the larger cities and even in Johannesburg we are advised that "no roof in the municipal fire limits may be constructed of thatch, reed or other inflammable material." The advantage of this characteristic is obvious. It is important, however, to consider that a roof may be fireproof from without while not fireproof from within. The material itself may resist ignition from sparks or firebrands falling upon it and yet be unable to resist any large amount of heat generated within the building itself.

The roof covering itself may be highly refractory and yet if laid on wooden sheeting, the roof as a whole is not fireproof. A wooden shingle roof supported on wooden sheeting is non-fireproof in both directions. A slate roof supported on wooden sheeting is fireproof from above only. A metal roof carried directly on steel purlins is fireproof from both sides.

Outside of the ordinary dangers from fire, some roofs possess an advantage over others in the case of lightning. Roofs constructed of good conductors of electricity do not require any other protection against lightning, as they serve to scatter the currents and thus dissipate their energies without danger of actual ignition.

4. *Durability*: Or resistance to wear. A good roof should last without repair as long as the building it covers stands without repair. Its material should not only look well but should also wear well, resisting abrasion from wind and weather and at the same time supporting any unusual live load which it may from time to time have to endure. A roof material which has to be handled delicately in putting it on has not very much in its favor, and the requirement in the case of some roof coverings that the workmen wear rubber soled boots when putting it on goes very far towards condemning that covering as a material for permanent uses. A covering satisfactory for dwelling houses may not do for a minute when laid on a roof garden. In this case the point at issue is that of the fitness of material. In some cases endurance is a matter of minimum thickness. Repeated complaints are made that the metallic roofing of the present day, whether iron, steel, tin, or terne plate, does not last as well as that made 20 years ago. A large part of the answer is that 20 years ago the extreme thinnesses of metal now in vogue were not in use and in consequence there was greater resistance to wear, corrosion and other deleterious elements. Assuming it to be a fact that processes of manufacture have improved in recent years, it is obvious that the endurance of the roof must be lessened either by the increase in deleterious atmospheric elements or else by the decrease in the thickness of the metal used.

5. *Least Expense*: The various items of watertightness,

wind resistance, fireproof character and endurance are all matters which affect the ultimate expenditure for a roof, and while the best is never the cheapest, it is the duty of the engineer to satisfy himself that the roof covering he will finally choose for the building in hand will be that which in the ultimate analysis gives the greatest service for the longest time at the least expenditure either for original cost or maintenance. Herein lies the necessity for the careful selection of a roof covering in accordance not with the statements of enthusiastic salesmen but with the actual whole truth as measured in terms of fitness expressed in coin of the realm. The first cost may be high and the maintenance cost low. It is the duty of the builder to balance these factors computed on the probable life and service of the structure.

This present discussion has to do with the materials of which a roof covering are made rather than with the framing of the roof itself. The choice of such materials is dependent upon a number of conditions:

1. *Character of the Building*: The engineer is called upon to construct every kind of a building from a pig pen to a palace, and it is obvious that no one roof covering will be satisfactory for every purpose. Buildings may be sub-divided, according to their character, into temporary, permanent and monumental, though the lines of demarcation between these classes are difficult to draw with precision.

On farms there are dwellings, barns, granaries, silos, corn cribs, garage houses, carriage houses, ice houses, smoke houses, coal houses, chicken houses, wood sheds, pig pens, etc.

At mines there are offices, company stores, hospitals, warehouses, tipples, head houses, power houses, breakers, smelters, oil houses, etc., etc.

On railroads there are general offices, terminal stations, way stations, train sheds, freight sheds, freight houses, round houses, machine shops, power plants, cold storage plants, oil houses, tool houses, water tanks, signal towers, car shops, storerooms, etc.

At steel plants there are administration buildings, including office buildings, chemical and physical laboratories, hospitals and other buildings equipped for purposes of superintend-

ence, scientific research, etc.: main mill buildings, including structures utilized in the actual manufacture of steel, such as metal mixer buildings, rolling-mill buildings, stripper buildings, open-hearth furnace buildings, heating furnace buildings, finishing mill buildings, gas producer buildings, etc.; special buildings requiring special treatment in roof construction, such as cast houses and blast furnaces, converter buildings or buildings in their immediate vicinity liable to receive excessive deposits of ore dust, dirt, etc.; shops, power plants and auxiliary buildings, including structures not immediately utilized in the steel manufacture but concerned in the physical maintenance of the plants, the furnishing of power, etc., as per the following detailed list:

Pattern Shops	Electric Stations
Roll Shops	Compressor Plants
Machine Shops	Store Rooms
Blacksmith Shops	Oil Houses
Bolt and Rivet Shops	Foundries
Fitting Shops	Warehouses
Splice Bar Shops	Gas Washers
Engine Houses	Ladle Houses
Pump Houses	Boiler Houses
Power Houses	Brick Sheds, etc.

In the cities there are permanent structures such as dwellings, hotels, club houses, bath houses, gymnasiums, churches, schools, theatres, hospitals, etc.; monumental buildings such as postoffices, courthouses, prisons, state capitols, cathedrals, libraries, art galleries, etc.

It is obvious that no one roofing material will be satisfactory to cover all of these buildings and that architectural and aesthetic considerations may in some cases have more weight than in others and that special attention must be paid by the designer to the uses for which the structure is intended. Cast houses and blast furnaces, for example, may require steel plates, rolling-mill buildings corrugated iron or reinforced concrete slabs, while administration buildings would naturally be roofed with tiles or slates, or again copper may be used on a building of the monumental type.

The classification of buildings into temporary, permanent,

and monumental is based on durability of the building rather than any other features.

2. *Atmospheric Conditions*: Materials which are affected by sulphurous gases should not be used without protection in proximity to industrial plants producing those gases; therefore, the roofing problem in a manufacturing town or in a mining community is quite different from that in an agricultural settlement.

3. *Geographical Location*: The type of roof to be used is very often settled by the location of the building with reference to the sources of supply and the familiarity of the artisans with the materials in hand. Consequently there are in different communities what might be called distinctive types of roof covering and the practice in this respect in the United States as a whole is quite different from that in England and Germany. The dwellings in Pittsburgh are roofed largely with slate and the porches with tin, whereas in the south-west the tin roof is the common roof, alternating with shingles, which latter is the common roof in lumber communities. Lead and zinc roofs are referred to by foreign publications on this subject as in common use, whereas in the United States zinc roofs are practically unknown and lead roofs infrequent, the methods of laying these classes of roof coverings being quite different from that with which United States workmen are familiar. Geographical location thus determines the type of roof to be used as viewed from the standpoint of the possibility of getting competent workmen to put it on. In the country districts it is hard to get workmen familiar with slate.

4. *Type of Roof Framing*: The covering material may be either self-supporting or not self-supporting. Its strength may be such as to permit it to be laid on purlins spaced five or six feet apart, or again it may be so weak as to require the use of tongued and grooved sheeting, and this consideration has largely to do with the design of the roof considered as a whole, so that in a way the type of framing to be used decides the question of roof covering and in a way the kind of covering used decides the type of framing.

5. *Roof Pitch*: Some roofing materials cannot be laid on

a steep roof. Other materials can be laid on roofs of all pitches, which in any event should be great enough to carry off snow or rain without difficulty. The greater the pitch the less chance for deterioration in the roof itself, though of course the greater chance for overturning from the wind. Cast houses and blast furnaces constitute a problem by themselves.

The classification of roofing materials is a matter which needs more important treatment than it has yet received in technical publications, and we need to distinguish between materials which are used as the body of the roof covering and those whose purpose is to protect that body from deterioration. Considered as materials, the best general division is that followed by the United States Geological Survey into metallic and non-metallic. The principal metallic roofing materials are copper, tin, zinc, lead and iron; the principal non-metallic roofing materials are wood, clay, stone, glass and fiber, the last sub-divided into animal, vegetable and mineral. Fibrous materials, with the exception of mineral fiber, are not as a rule self-supporting and for roofing purposes require further treatment or impregnation with asphalt, tar, pitch or some other substance to make them watertight, the fiber giving body to the compound while the other constituents give watertightness, and in the consideration of fibrous materials we want to remember that the impregnating substance is a preservative or binder only and that tar, pitch and asphalt sustain practically the same relation to fibrous materials as paint does to metals. There are also primary and secondary uses of these materials, and the tentative classification which follows is intended to take account of these various features and to co-ordinate the various roofing materials into a comprehensive scheme.

METALLIC ROOFING MATERIALS

COPPER

A. *Characteristics*: The most durable, but dear, roof material, light and strong. Coefficient of expansion medium, 0.0009 in 100 deg. Fahr. Support frame work light. Oxidizes on exposure to air with formation of insoluble green carbonate which protects it from further decomposition. Almost imperishable and from a structural point of view the best available material for roofing government and other

monumental buildings, although its heat conducting properties require it to be well insulated by layers of felt or other non-conductors.

B. Primary Uses: Laid on wooden sheeting in flat sheets with standing or welted seams or with wool rolls at intervals of sheet widths which are usually two feet to 3 ft. 6 in. wide, four to five feet long, 24 gauge weighing 16 oz. per sq. ft. May be laid on any pitch as flat as 250:1 or as steep as desired, surfaces flat, curved or warped. Weight per square foot including lining, sheeting and rafters 4¾ lb. Laid also corrugated on steel purlins or sub-purlins, also on sheeting in the form of copper tiles.

C. Secondary Uses: Alloyed with nickel and iron to make monel metal and rolled into sheets having lightness and stiffness with the durability of pure copper at less expense, laid on sheeting or sub-purlins. Electrolytically deposited on steel or iron, or mechanically welded between rollers to form copper clad sheets, copper on one or both sides, combining again the strength and stiffness of steel with the weather resistance of the copper. Used also in very small percentages in steel manufacture to make Ingot Iron, Vismera, Toncan, Copper Steel or other steel or iron sheets to increase their resistance to corrosion; the copper being put in the ladle by design or already contained in the ore. Made either pure or alloyed into flashing, cornices, gutters, down spouts, conductors, finials, cresting, etc., also lightning rod points, etc. Copper or copper coated nails are the best for use on all metallic roofings. Water collected from a copper roof or from copper channels must not be used for dringing or culinary purposes.

TIN

A. Characteristics: A soft and malleable metal having great ductility which can be hammered or rolled into very thin sheets (tin foil). Unchangeable in air at ordinary temperature and, therefore, very durable. Coefficient of expansion high, 0.0017 in 100 degrees.

B. Secondary Uses: Admirable as it would be from the standpoint of durability, pure or commercially pure tin is not used for roofing; indeed it is not much used in the arts at all. Tin plate consists of sheets of iron or steel coated with tin in a molten bath; terne plate is a similar product, but the bath is of tin and lead mixed, the latter being 75 to 90 percent of the whole. The best and most uniform sheets are rolled after the bath. Coating weighs 8 to 10 oz. per sq. ft., of which 3/10 to 1-7/10 oz. is tin. Iron sheets in former use for coating were coke iron and charcoal iron; as the latter being the better received a heavier coating, "charcoal tin plate" stood for quality. Tin plate or terne plate are apparently not in use in England and on the European Continent, except Russia, as roof materials. The tin roof is an American invention and even that is now almost exclusively laid with terne plate. Tin roofs are laid on wooden sheeting preferably

covered with felt or roofing paper which must be dry with horizontal seams welted and transverse seams welted or standing, with all seams soldered in high class work. May be laid on any pitch but on flat roofs seams should all be welted or soldered. Terne plates should not be used where subject to action of corrosive gases which destroy the lead in the coating. Tin roofs need protection with paint on both sides, beneath before laying, above with frequent renewals. Hydro carbons should not be used for first coat; best paint 10 lb. venetian red and one pound red lead to a gallon of pure linseed oil. Life, if kept painted, 30 years or more. Weight per square foot, including lining, sheeting and rafters, 4½ lb. Terne plate less than 28 gauge should not be used on permanent roofs. Metallic shingles, tin or terne coated, also in small use. Tin or terne plate in wide use for flashing metallic and non-metallic roofs, valleys, gutters, spoutings, etc.

ZINC

A. Characteristics: Light, strong, durable, inexpensive; stronger than lead or tin, weaker than copper, iron or steel; less durable than lead, tin or copper, more durable than iron or steel. On exposure to air top surface oxidizes and protects metal beneath from further change and obviates the necessity of painting. Coefficient of expansion high 0.0016 in 100 deg., therefore, sheet zinc must be laid free to expand and contract. If of good material, laid with care and attention to expansion, "sheet zinc roofs are very commendable as simple, cheap and durable but not for places of large manufacturing activities because soot and smoke gases very soon destroy the sheet zinc. Sheet zinc is to be kept away from fresh lime or cement mortar by tar paper or paraffin paper." Worst impurity in commercial zinc is iron. Sheet zinc is used in the United States in the manufacture of tanks to *contain* water or other liquids, not as a roof material. In England and Germany it takes the place of tin and terne plate not only to contain but also restrain water; American tin roofs—English and German zinc roofs.

B. Primary Uses Abroad: Flat sheets 36 to 40 in. wide to 7 or 8 feet long, 19 to 25 gauge, weighing 24¾ to 11½ oz. per sq. ft. Laid on wooden sheeting with single welted seams on all four sides of the sheet or with standing double seams, in either case folded or folded and soldered. Least slope of roof usually 3:1, in any case not less than 6:1, better not less than 4:1. Weight per square foot, including lining, sheeting and rafters, 8.2 lb. On account of expansion best method of laying is with wood rolls about 2 by 2 in., spaced four inches less than width of sheet, against which the sheets are folded and capped with zinc caps. Four systems of such laying, English, Belgian or Rhenish, French and Frik, dependent upon shape of rolls and kinds of clip fastenings. Fastened with copper, zinc or galvanized nails (iron or steel nails should not be used with zinc or galvanized roofing).

Rhomboidal sheets, either square or pointed, laid with rolls or nailed like shingles, 31 squares or 125 pointed rhombs to the square. Slope at least 2 : 1.

Grooved roofing used only for quite flat roofs, balconies, etc., laid in cast grooves into which the sheets are inserted; open joints covered with joint roof tile, or the sheets may be butted together and joints closed by seams and edging.

Corrugated sheets laid on purlins spaced two to four feet and fastened by clips soldered to under side of sheets, or else laid on lathing or sheeting dependent upon thickness of metal.

Weight per square foot corrugated zinc roof five to six pounds. Slope 1½ : 1 or steeper to 3 : 1.

Felt laid beneath zinc lengthens the life of the roof, prevents the sheeting from cutting the sheets if it warps and acts as a cushion if there is traffic across the roof.

Failure to use sheet zinc for roofs in the United States is probably due to ignorance as to methods of application, to the difficulty of getting good material, or to climatic conditions. At any rate, its use seems unknown. Possibly a good commercial organization with aggressive, intelligent salesmen could make a decided change in such conditions.

C. Secondary Uses: Deposited on iron and steel to prevent corrosion either in molten bath (hot galvanizing) or in an electrolytic bath (cold galvanizing) or in a retort by the dry galvanizing process called Sherardizing. Used also for cornices and roof ornamentation.

LEAD

A. Characteristics: The heaviest metallic roof covering; more durable than zinc, more resistant to attack by impure air. Ductility great, therefore, must be laid on close or tongue and groove sheeting. Easily dressed and worked into awkward corners without jointing. In spite of painting with oil paints lead is gradually destroyed by oxidation, and rain water is, therefore, poisoned. Low melting point in case of conflagration. Coefficient of expansion high, 0.0016 in 100 deg., necessitating allowance for expansion and contraction.

B. Primary Uses: Flat sheets laid on wooden sheeting with the aid of rolls and drips, on roofs of steep slope; on flat roofs usually laid with some grooved system to avoid the formation during hot weather of rolls and hollows. Sheets, 40 to 96 in. wide up to 35 feet long, 1/14 to 1/7 in. thick, most suitable weights seven or eight pounds per square foot for flats and gutters, six for ridges and hips and five for flashings. Weight per square foot, including wood sheeting and rafters, 12 lb. Slope 3½ : 1 or less. Common in England and Europe on public buildings, but little used in the United States.

C. Secondary Uses: Prime constituent for coating steel and iron to make terne plates. Used to some extent for conductors, gutters, etc. Alloyed with antimony it makes Wetterstedt's parent marine metal whose advantages are malleability, great tenacity, elasticity and durability, also its resistance to acids, oxidation and the action of sun and wind.

IRON AND STEEL

A. Characteristics: Cheap and strong. To a large extent self-supporting, therefore, requires a framework of light construction. Stiffness of sheets hinders formation of seams. Advantages: small weight, security against fire, good water conductor, large purlin spacing, minimum number of joints, support by lathing or sheeting unnecessary. Disadvantages: great heat conductivity, cold in winter, warm in summer, formation of condensation water and drip from rain fall, very sensitive to oxidation. Coefficient of expansion low, 0.0007 in 100 deg. If protected against corrosion the ideal material for roofing mill and factory buildings, barns, etc., etc. Slope 2½ : 1 or 3 : 1. Weight, 20 gauge, laid on steel purlins, six pounds, on sheeting eight pounds.

B. Primary Uses: Flat sheets laid on sheeting with welted longitudinal seams and standing transverse seams. Small sheets laid on lath and nailed shingles. Corrugated sheets laid on purlins with end and side laps and riveted or fastened with clinch nails, clips and bolts, etc. *V*-crimp sheets nailed to *V*-shaped sticks on sheeting with longitudinal seams made by lapping. Flat plates laid on sub-purlins.

C. Secondary Uses: Used for ridge rolls, valleys, gutters, cornices, especially cast iron, ornaments, etc., also for nails, screws, bolts, rivets and other fittings.

D. Protection: The great advantages of steel and iron appear in measures taken to protect them against corrosion, which is their main foe, thereby enhancing their durability. These measures are:

1. Expedients in raw manufacture. The elimination of substances, such as carbon and manganese, which may induce corrosion, and the addition of nickel, copper, etc., to prevent it.

2. Expedients in finished manufacture. Coating the sheets with tin—tin plate; with lead and tin—terne plate; with zinc—galvanized iron; with copper—copper clad sheets; with aluminum—aluminum coated sheets; with nickel—nickelized sheets.

3. Expedients after manufacture. Coating the sheets with non-metallic substances; with asbestos—Asbestos Protected Metal, Corrugated Asbestos Roofing; with cement—Ferroinclave.

4. Expedients after laying. Coating the sheets, plain, coated or protected, with paint, the last and best resort and the only resort needed if the paint is mixed with intelligence, applied with honesty and

renewed with judgment. The first coat should be an inhibitive and a shop coat; the second coat should be a proved excluder. Both pigments and vehicle should be pure, and there should be a pigment weight in pounds of three times its specific gravity to a gallon of oil.

Caution. Avoid thinness of metal; avoid cheapness of paints. The first rule will solve half the roof trouble; the second the other half.

NICKEL, ETC.

Nickel is used in alloy with copper as Monel Metal, also in making nickelized sheets. It is possible that a nickel-steel sheet would give good service.

Aluminum is used in aluminum coated sheets; there is no good reason why a pure aluminum sheet should fail to give satisfaction on monumental buildings where expense is not a large consideration.

NON-METALLIC ROOFING MATERIALS

SLATE

A. Characteristics: A strong, though brittle, and very impermeable material, easily split into thin plates, low in cost and suitable for dwellings and other permanent buildings. Fireproof as far as sparks are concerned, but will crack and disintegrate under heat. Durability dependent in large measure upon kind of nails used, quality of slates and care in laying. Liable to decay if not ventilated. Slope not less than 2 : 1. Weight per square foot, including sheeting and rafters, 18 pounds.

B. Primary Uses: Slates vary in length from 6 by 12 in. to 24 by 44 in, ⅛ to ¼ in. thick. Various colors—blue, blue-gray, gray, purple, green, red and variegated; best slates have a glistening, semi-metallic appearance. Slates with a dull earthy appearance will absorb water and suffer from frost. Laid on lath like shingles, or on plank sheeting, which should be tongued and grooved, or upon battens fixed upon sheeting, and nailed thereto by copper, zinc or galvanized nails driven through holes in heads of the slates; center nailing also in use but not customary, though stronger than head nailing. When close sheeting is used it should be surfaced and covered with asphalted or tarred felt or treated roofing paper. Well to lay edges at least in slaters' cement; cemented joints should be used around eaves, ridges and chimneys. Laid also on and wired to steel sub-purlins; also in cement on concrete sheeting reinforced with wire lath or expanded metal to make a fireproof roof.

TILE

A. Characteristics: Made from clay and burned like bricks, with top surface vitrified or glazed, or else unglazed but nearly non-porous terra-cotta. Quality dependent upon the burning; underburnt tiles,

porous, weak, liable to early decay; overburnt tiles more durable but liable to warp and less uniform in color. Obtainable in many different shapes and colors which improve with age. The most decorative roof material, lends itself readily to architectural treatment and most suitable for monumental buildings. Fine for use on cupolas, towers, etc. Resistant to corrosive gases, life 50 years or more according to goodness of the tile. Slope not less than 1¼ : 1. Weight per square foot 22½ lb. including rafters and sheeting. Various kinds, plain tile, book tile, Spanish tile, pan tile, Ludowici tile, hollow tile. Liable to breakage in handling, especially at interlocking edges.

B. Primary Uses: Plain tiles may be laid on plank sheeting, on concrete and expanded metal or wire lath sheeting, or else on angle sub-purlins, or again on battens fixed to the wood sheeting. May be fastened to sheeting or battens by nails, to sub-purlins by wires. May be laid on sheeting with lime or cement mortar. Pan tiles merely overlap each other at the edges and must, therefore, be bedded in cement and pointed inside and out. Ludowici terra-cotta tiles interlock, require no cement except in special cases and are fastened to angle sub-purlins at every fourth piece by (copper) wire. Anti-condensation lining required when there is danger of excessive sweating. Hollow tile laid on flat roofs in the same way as in floors and may be waterproofed with asphalt, tar, etc. Common in use on office buildings. Abroad, straw mats in common use for bedding the joints of pan-tiles.

C. Secondary Uses: Used abroad for valleys under lead roofs, etc.

GLASS

Used for conservatory roofs, skylights, etc.: small panes, single or double thick, set in putty on wooden sash in the cheaper work; large panes set on steel or iron bars in lead or cement. Large sheets make fewer joints but are easier broken by hail or blown in by wind; therefore, glass is now used for skylights, etc., with wire mesh enclosure—wire glass. Bad conductors of heat; large sheets must, therefore, have freedom of movement with clearances on all sides. Special skylight sections, therefore, in use, with ledges for glass to rest upon, stems for receiving the clamp bolts with grooves below to carry off moisture, though plain tees may be employed where moisture feature is of no consequence, joint covers or capping of copper or zinc. Asbestos sometimes in use as a bedding material to give firm joints without breakage. Slope at least 3½ : 1, better 2 : 1 or 1 : 1. May safely be flatter in courts protected by high walls. Weight per square foot including purlin bars four, five and six pounds for glass ⅛, 3/16 and ¼ in. thick.

WOOD

A. Characteristics: A material of many qualities, excellent in many respects, such as strength, stiffness, lightness, etc.; good, bad

and indifferent as concerns the species in use. The roofing material of new countries. Cheap and fairly durable under any conditions, proof against acid action but not against fire. Therefore, suitable for dwellings and cheaper buildings in country places. Now very seldom used in mill buildings and not at all fit for permanent structure. Durability increased by creosoting, staining, dipping in oil, etc. Can also be protected by paint, but treatment should always be applied before laying. Liable to twist and warp under hot sunlight. Slope not less than 2 : 1. Weight, including rafters and lath, 10 lb. per sq. ft.

B. Primary Uses: Shingles riven by hand from the solid block or sawed taper on special saws. Made of white oak, white pine or spruce, Oregon fir, cedar, cypress or other straight grained stuff. Cedar the best. Chestnut sometimes in use but more liable to rot. Oak shingles more liable to warp than soft woods. Laid on lath and nailed at upper ends with four inches end lap. If well made of good stuff, life of roof dependent on the nails. Capable of decorative treatment by variations in shapes and staining. Flashing usually of tin or terne plate.

C. Secondary Uses: The usual material for sheeting and lathing under all kinds of roofing except corrugated sheets, glass and other types laid on sub-purlins.

FURNACE PRODUCTS

Slag and cinders used for filling and surfacing. Granulated slag used also for making concrete. Products of very variable character and of quite uncertain results. Slag should be bank slag well seasoned; and should not come in contact with raw steel.

FIBER

A. Characteristics: Materials of diverse value, usually cheap, of low durability unless treated, fireproof or not as regards kinds, suitable as a top cover only for temporary or cheap construction, most suitable for anti-condensation work or bedding of more durable roofings. The basis of ready or prepared roofing in which often two or three kinds of fiber are used in same roll. All modern fibrous roofings laid on wood sheeting or reinforced or plain concrete base. Fibrous materials impervious partly by reason of density and thickness, partly by absorption of waterproofing compounds. The best absorbants make the best roofings. Permanence obtained by frequent renewals of protective coatings. Subdivided as regards origin into Vegetable, Animal and Mineral fiber.

B. Primary Uses: *1.* Vegetable fiber—Savage people roof with fibrous leaves laid on poles and held in place by grass ropes, etc., or by weights. Tahiti islanders thatch with leaves of pandanus (screw pine). Other natives with various grasses; wheat growing peoples with straw, Indians with bark. Civilized peoples weave hemp into canvas, jute

and sisil into burlap, cotton into felts; manufacture straw, wood pulp, etc., into paper, impregnate with chemicals or hydrocarbons and lay with or without painting. Mostly used in rolls. Vegetable fiber must be fireproofed, deteriorating rapidly under heat. Fragile to lay. A tent is a frame with canvas roof.

2. Animal fiber—primitive peoples remove hair and tan the hides of animals to make tent coverings; civilized peoples make the hair into felts, impregnate with hydro-carbons and lay. All wool felt best saturatant, slow burning; best for bedding. Cost leads to much adulteration. Used in rolls.

3. Mineral fiber—Asbestos a natural fibrous substance in use for centuries, high resistance to fire and acids, fair saturant ,wears well. Actinolite slightly different chemical composition, same physical qualities. Asbestos made into rolls, shingles, boards, etc., nailed in place and protected by heavy paints.

C. Well Known Fibrous Roofings: Fibrous roofings take their names not from the kind of fiber but from kinds of protective coverings. Classified into: 1. Built Up Roofs; 2. Ready Roofing.

Gravel Roof: A built up roof of felt or roofing paper laid on sheeting mopped and cemented together with roofing cement, tar or asphalt and covered with gravel. May also be had as ready roofing.

Slag Roof: The same kind of roof covered with blast furnace slag.

Cinder Roof: The same kind of a roof covered with cinders.

Asphalt Roofing: A built up roof of felt cemented with Trinidad roofing cement covered with a coating of asphalt and screened gravel applied hot and together. May also be had as ready roofing.

Asbestos Roofing (H. W. Johns-Manville Company kind): Composed of a strong canvas foundation between two layers of asbestos felt, lower layer plain, upper layer saturated and finished with a sheet of plain asbestos. The whole cemented and compressed into a flexible roofing. Does not require painting, but best to do so.

Carey Roofing: A ready roofing made of a layer of asphalt cement composition on a wool felt foundation with burlap imbedded in the upper surface of the cement, and covered after laying with a tough elastic cement which dries to a surface like slate. Practically acid proof and a slow burner.

Granite Roofing: A ready composition roofing with quartz pebbles imbedded in upper surface.

Ruberoid Roofing: A ready roofing of wool felt saturated with a special water and acid proof compound and afterwards coated with a hard solution of the same compound.

D. Slopes, etc.: The life of fibrous roofings depends, more than all others, upon the quality of the materials, the carefulness of the work and the thoroughness of the preservative treatment. Vegetable

and animal fiber decay readily, break easily and wear badly. They stretch and wrinkle, single defects cause leaks and their chief value lies in their secondary uses. Built up roofs are suited to flat slopes only. A gravel roof laid with asphalt binder should slope not more than 24 : 1 (½ in. to the foot) else it will run in hot weather; laid with tar 12 : 1; prepared roofing not more than 4 : 1. Weight per square foot including rafters and sheeting; gravel roof 12 lb., asphalt roofing 11 lb., prepared roofing 4½ lb.

Caution: Do not lay fiber roofs thin, do not scrimp the paint.

E. Binders: The following bitumens or hydro-carbons are in use in preparing built up or ready fibrous roofings:

1. Natural Asphalt: Principal varieties from Bermudez, Trinidad and Sicily; the best. Gilsonite: From Colorado and Utah, not a good saturant. Elaterite: From Colorado and Utah. Grahamite or Choctaw: From Oklahoma, satisfactory for paving, not much for roofing. Mastic Rock: From California; rare in roofs.

2. Artificial. Petroleum Residuals, the refuse after fractionation of crude petroleum. Best from California. Coal Tar: Usually used in the form of coal tar pitch. Water Gas Tar: By-product from gas plants. Pine Tar: Too good for roofs.

The best is the purest. Bitumens should be free from mineral matter, grit or dirt.

DISINTEGRATED ROCK

A. Characteristics: Except as slate, the most enduring of materials is not used for roofing in its natural condition owing to its great weight. Small pieces, gravel, crushed quartz, etc., are used for surfacing. So also is gypsum, sparham, etc. For these purposes cleanliness and angularity are the best recommendations, with resistance to wear. Sandstones, granites, quartz are suitable, limestone may slake or be subject to acid attack. Best used when made into artificial stone, concrete or neat cement, the advantages of which are molding ease, resistance to wear, resistance to fire, low expansion ratio. Disadvantages, weight unless reinforced, liability to edge breaking, perviousness to water.

B. Primary Uses: Cement tile, reinforced concrete tile interlocking or otherwise laid on purlins and fastened by galvanized clips, or plain cement laid on hollow tile and trowelled to a hard finish.

C. Secondary Uses: Concrete used in place of wood for sheeting whether in the mass as a roof arch, or reinforced as a slab. In the former case laid in office buildings, etc., in the latter case on mill buildings, etc. Probably the best field for its use.

STEAM POWER PLANTS

By O. S. Lyford, Jr.* and R. W. Stovel†

It has been suggested that this discussion deal first with the desirable characteristics of a power plant for coal mining; second, with those of a power plant for a public service corporation; third, with those of a power plant for a large manufacturing establishment; and fourth, with the factors which cause the differences between the designs of plants in the vicinity of Pittsburgh and those of other localities. These suggestions are indicative of a natural desire frequently expressed, namely for a set of power plant plans that can be taken down from the shelf and adapted to any condition that may arise. The fourth suggestion also illustrates a general feeling that geographic location has much to do with the design of the plant.

As a matter of fact the variables in each of the three classes of power stations are so many that it is seldom that one station can be built like another, even where the conditions at first seem to be substantially the same. For instance, in two different coal mining operations for the same daily output, the power plant of one may have twice the capacity of the other, because of differences in local conditions. Furthermore, the equipment of either of these plants may be any one of an unlimited number of combinations, depending upon the proportion of power for pumps, hoists, fans, air compressors, coal cutting machinery, locomotives, breaker engines and miscellaneous apparatus to be served from the main plant; moreover, a power plant to serve an entirely new mining development is a very different matter from one which is to serve an old and fully equipped property, for in the former case electrical operation can be used to financial advantage on a much larger scale than in an old

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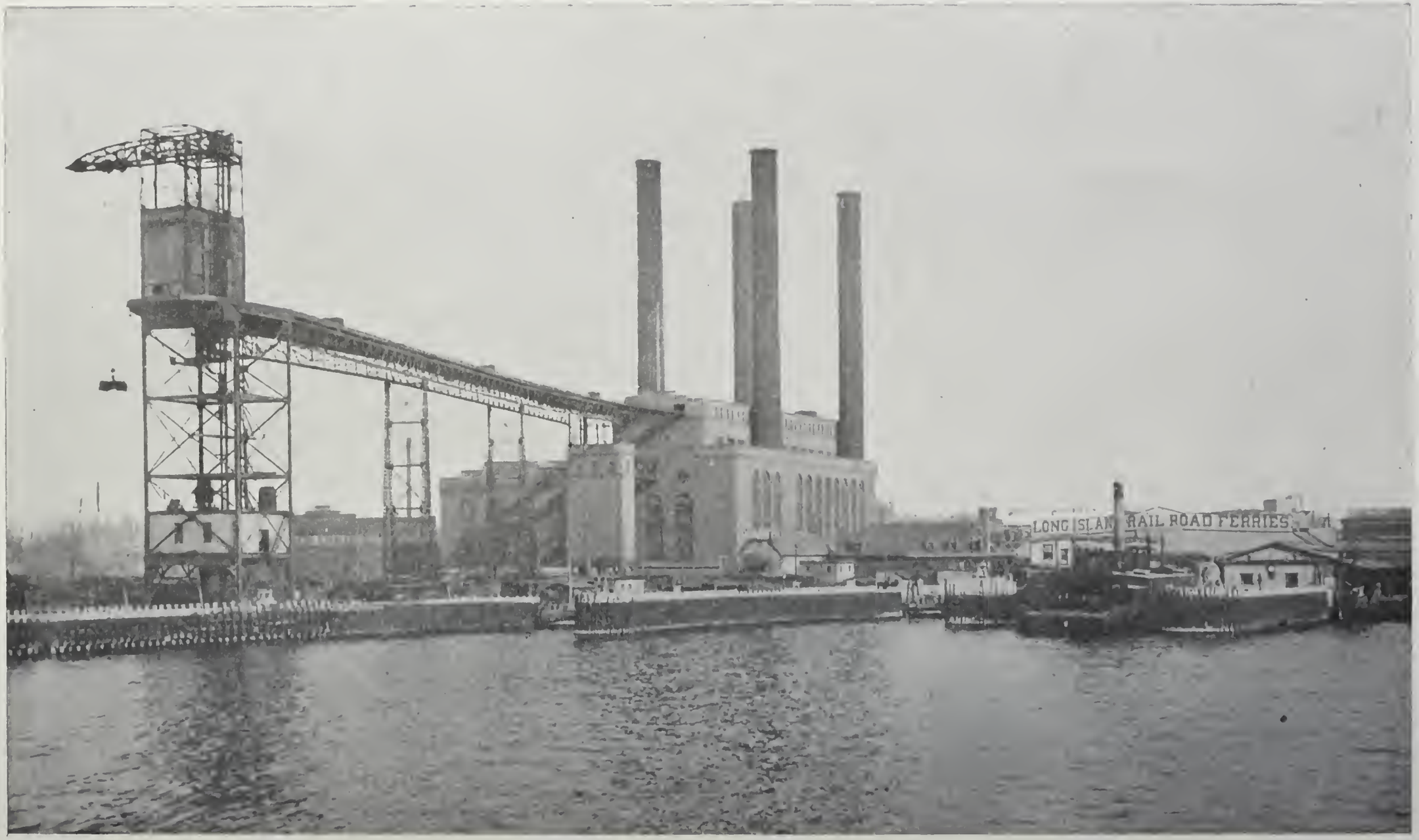

Fig. 1. Pennsylvania Tunnel & Terminal R. R. Co. Long Island City Power Station.

development in which first-class steam driven equipment has already been provided.

Referring to the other two suggested classes of power plants, it is very possible that suitable characteristics for a small public service plant and for a manufacturing plant would be identical, whereas the characteristics of two different public service plants may vary widely.

It is therefore impracticable to definitely classify power plants; furthermore, a brief discussion of all the types of power plants commercially posible for either service would necessarily be very general and not particularly instructive. Hence this paper must be limited to one class of plants, and in view of the extensive use of electric transmission in all three of the fields which we have been asked to consider, also in view of the fact that the steam turbine is now available for driving all kinds and sizes of electrical generators, and finally because bituminous coal is the fuel most generally used in this district, the paper will be limited to steam turbine driven electric plants, using bituminous coal for fuel.

Even when limited to this class, there are so many factors involved, that each plant is still necessarily an individual study and no general rules governing all cases can be formulated. Irrespective of whether such a power plant is to be used for a coal mine, a public service utility, or a factory, the most important conditions which govern the design and construction are as follows:

Character of Load to be carried. (High or low load factor, steady or fluctuating).

Location of Plant with reference to fuel and water supply.

Local Conditions affecting the dimensions of the building and the construction of foundations and flumes.

Relative Costs of available material and apparatus.

Fitness of Various Types of apparatus to the duty to be performed.

Costs of Fuel and Water.

Proper Relation Between Operating Costs and Fixed Charges, under the conditions imposed.

Fig. 2. New York, New Haven & Hartford R. R. Co. Cos Cob Power Station.

Finally, there is the element of *Personal Preference of the Client,* which is the deciding factor in the selection between types or methods that may cost practically the same and are economically equivalent; in fact, there are cases where such personal preference of the client, or his commercial relationships, predetermine the make of materials and apparatus.

As an indication of how these conditions cause variations in the arrangement of buildings and apparatus, we selected from the recent work of our Company ten characteristic power stations. These are central stations for *railway, light* and *power* service built for ten independent operating companies in various parts of the country. Some are entirely new, others are older stations, to which additions have been recently made. They are all steam turbine stations using coal for fuel. They vary in capacity from 79 000 down to 1 000 kilowatts. A striking point in the comparison is the variety found necessary in the combinations of equipment and in the methods of housing these ten stations. Four types of building construction are used; six types of boilers; three methods of stoking; three kinds of draft for furnaces; ten methods of handling coal; two types of turbines and generators; seven types of condensers; exciters of four types, and various characteristics of electrical equipment.

It is difficult to get instructive photographs of the interior arrangements of such stations, but pictures of the exteriors of some of them will perhaps be of interest, as the variations in appearance of the buildings give a fair impression of the variations of interior details when these are carefully analyzed. When it is borne in mind that these stations are all designed by one firm of engineers, with a natural desire to maintain uniformity of design—the impossibility of evolving conventional designs for power plants will at once be apparent.

Pennsylvania Tunnel & Terminal R. R. Co.: Station at Long Island City, N. Y. See Fig. 1. Ultimate capacity 58 500 kw. Present installation has thirty-two 520 h. p. boilers; seven turbo-generators aggregating 48 500 k.w. Supplies power for operation of Pennsylvania tunnels and electrified lines of the Long Island Railroad.

Fig. 3. Hartford Electric Light Company. Hartford Power Station.

New York, New Haven & Hartford R. R. Co.: Station at Cos Cob, Conn. See Fig. 2. Ultimate capacity 35 500 k.w. Second section now being built has twelve 625 h. p. boilers, three 5 000 k.w. turbo-generators. Station supplies single-phase electric current for operation of main line of N. Y. H. & H. R. R. entering New York City.

Hartford Electric Light Company: Station at Hartford, Conn. See Fig. 3. Ultimate capacity 21 400 k.w. Present installation has six 500 h.p. and four 1250 h.p. boilers. Six turbo-generators aggregating 17 400 k.w. Supplies light and power to Hartford and vicinity.

Worcester Electric Light Company: Power Station at Worcester, Mass. See Fig. 4. Ultimate capacity 10 000 k.w. Present installation has six 600 h.p. boilers, three 2500 k.w. turbo-generators. Supplies light and power to Worcester and vicinity.

This station is located near a residence section of the city, and the client desired that the building be sufficiently ornamental to correspond with the surroundings. The building construction is of brick with steel frame, and cement stucco. It is interesting to note that the difference in cost per cubic foot for a building of this type is within 10 percent of the unit cost of such a building as the Hartford plant, Fig. 3, or the Utah plant shown in Fig. 5. The architectural treatment, however, involved greater head room than absolutely necessary and therefore the building cost per kilowatt of power station capacity was somewhat more than 10 percent in excess of what the plainest type of building would have cost. This illustration shows one way that a reasonable amount of ornamentation can be obtained without much expense.

Utah Light & Railway Company: Power Station at Salt Lake City, Utah. See Fig. 5. Capacity 8 500 kw. Equipment comprises six 600 h.p. boilers, one 8 500 k.w. turbo-generator. Building volume 56 cu. ft. per kilowatt. Station acts as a relay to various hydro-electric plants.

In this building design, the dimensions are determined solely by arrangement of equipment and necessary working space.

Absolutely nothing has been spent for extra architectural treatment.

Northern Colorado Power Company: Power Station at Lafayette, Colo. See Fig. 6. Capacity 7 500 k.w. Ten 411 h.p. boiler units; four turbo-generators aggregating 7 500 k.w. mechanical draft is used. Station supplies light and power through the district north and west of Denver, Colo.; also single-phase current for the Denver & Interurban R. R.

Central Indiana Lighting Company: Station at Columbus, Ind. See Fig. 7. Ultimate capacity 1 000 k.w. Present installation two 300 h. p. boilers; one 500 k.w. turbo-generator. Station supplies light and power to Columbus and vicinity.

Fig. 4. Worcester Electric Light Company. Webster Street Steam Station.

It will be noted that these seven stations cover a wide range of locations and capacities, but are limited to electric light and power service. A few additional stations have been selected at random to illustrate power stations built for other purposes.

Fig. 5. Utah Light & Railway Company. Jordan Steam Station.

Chicago, Burlington & Quincy R. R., Havelock, Neb.: See Fig. 8. Ultimate capacity 2 500 k.w. Present installation 950 k.w. Four 400 h. p. boilers; one 200 k.w. engine-driven unit; one 750 k.w. turbo-generator; two 2000 cu. ft. air compressors. Station supplies light, heat and power for railway shops.

Chesapeake & Ohio R. R., Huntington, W. Va.: See Fig. 9. Ultimate capacity 1 125 k.w. Present installation five 275 h. p. boilers; two turbo-generators aggregating 625 k.w.; two air-

compressors aggregating 3 000 cu. ft. capacity. Condensation of steam effected with water from air cooling system seen in the foreground. Station supplies light, heat and power for railway shops at Huntington, W. Va.

Pittsburgh & Lake Erie R. R. Service Power Plant for Pittsburgh Terminal Station. See Fig. 10. Capacity 360 k.w. Three 230 h. p. boilers; three 120 k.w. D. C. generators driven by reciprocating engines. Plant supplies heat, compressed air, refrigeration, water, light and power for Pittsburgh Terminal Station.

Fig. 6. Northern Colorado Power Company. Lafayette Power Station.

Hamilton Manufacturing Company, Lowell, Mass.: See Fig. 11. Boiler plant only, six 500 h. p. boilers. Supplies steam for heat and power for manufacturing purposes.

Foundations: The foundation problem is one which has to be worked out for each individual case.

Fig. 12 is a sectional drawing of the Northern Colorado plant and illustrates a case where good bearing soil and freedom from surface water permitted the use of simple concrete footings.

At Hartford the bearing quality of the soil was poor and a very careful study of the condition of substrata was necessary. See Fig. 13. The required loading permitted the use of piles in lines and bunches. See Fig. 14.

Fig. 15 shows a cross-section of the Long Island City Power Station of the Pennsylvania Tunnel & Terminal R. R. at New York. This cut illustrates, among other things, the foundation and flume construction necessary in the case of a very large power station located at tide-water on valuable real estate. This

Fig. 7. Central Indiana Lighting Company. Columbus Power Plant.

station is on filled land, with a considerable depth of filling and river mud, above gravel and sand that overlies the bed rock. The foundation was therefore made of a solid concrete mattress, averaging 6½ feet thick, resting on 35-foot piles, driven two feet four inches apart over the entire area.

A radically different type of foundation was used in the Detroit Edison Power Station. See Fig. 16. The site of this station is on blue clay, firm in the upper stratum, but quite jelly-like lower down, though of good supporting power when

there is no possibility of its yielding sidewise. To secure uniformity of settlement, this foundation is composed of a concrete mattress covering the whole area, reinforced throughout but not supported on piles. The mattress is uniformly 4½ feet thick, and the reinforcement is composed of 1¼ inch steel rods suitably spaced. The flumes of this station run along the edge of the mattress, just outside the face of the main building at the engine room end, underneath the pump house, which is a one-story addition to the engine room.

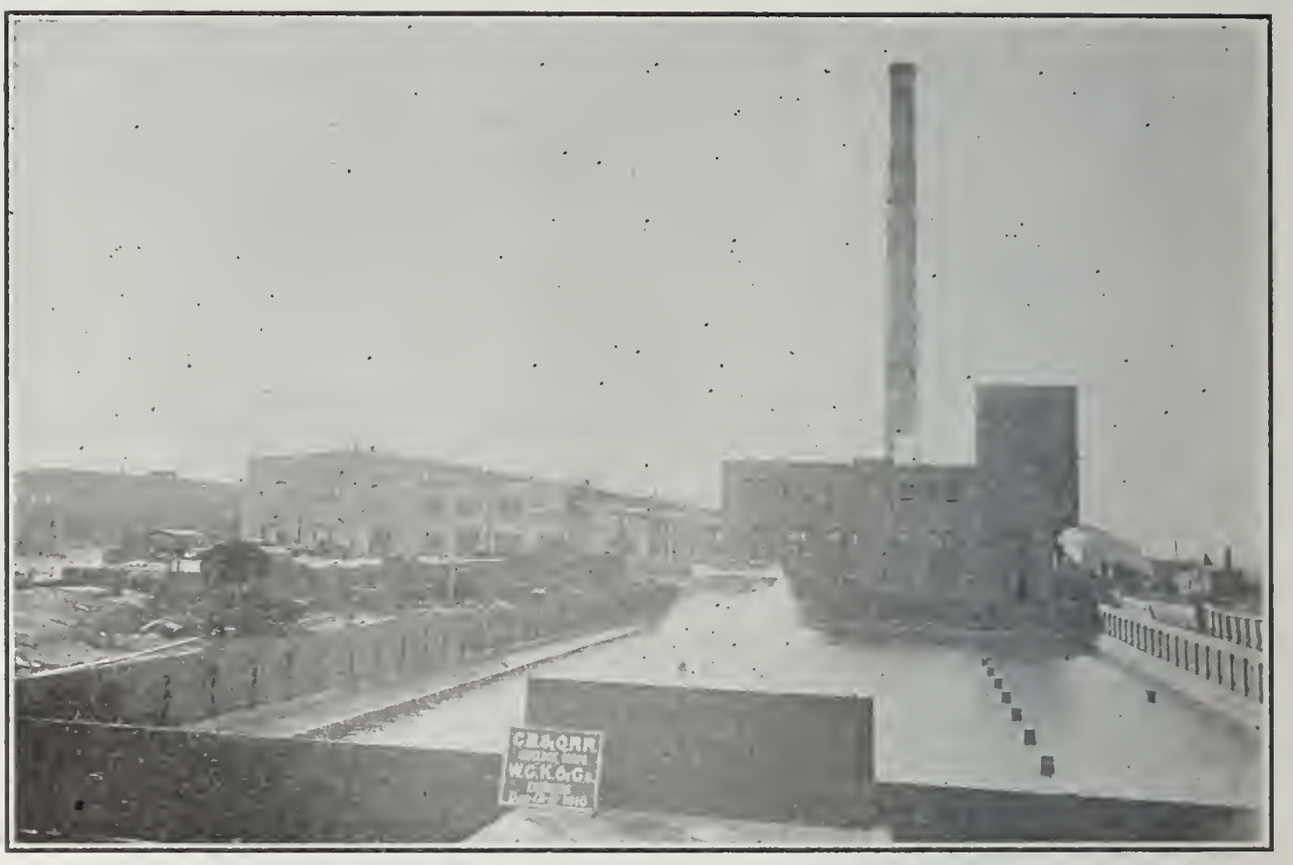

Fig. 8. Chicago, Burlington & Quincy R. R. Co. Power Plant at Havelock Shops.

The intake and overflow flumes are usually brought directly under the condenser and formed in the foundations. The design of these flumes often requires much study; for instance, on inland rivers, which are subject to a variation of from 20 to 30 feet in depth, the problem may be quite complex.

The other extreme from Long Island City with its piling sometimes occurs as in the case of Cos Cob, where to get the condensers low enough very extensive excavation into solid rock was necessary.

Figures 17 to 20 illustrate characteristic engine rooms for the two prevailing types of turbines.

Figures 21 and 22 illustrate characteristic boiler rooms, one with underfeed stokers and the other with those of the overfeed type. Attention is called to the fact that both these photographs were taken with natural light. Contrast them with the usual dark boiler room, dependent entirely on insufficient artificial light.

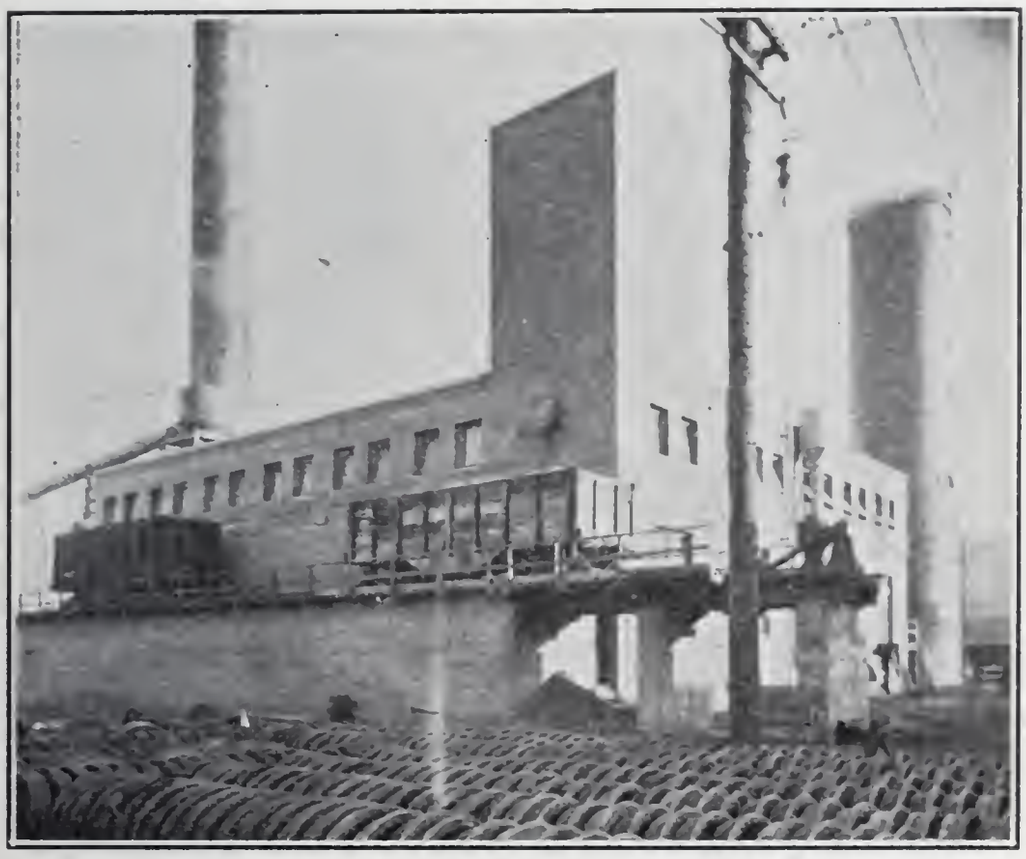

Fig. 9. Chesapeake & Ohio R. R. Company. Power Plant at Huntington Shops.

Figure 23 shows the cross-section of a power plant recently designed and put in operation for the Utah Light & Railway Company at Salt Lake City, Utah.

This drawing shows clearly the present day relative size of the boiler room and turbine room, both of which are the same length. This plant is designed as a unit, provision being made so that it may later be extended in either direction. This factor necessitated placing the stack to one side of the boiler room and carrying the flue for the interior line of boilers across the room above the central firing aisle.

This boiler plant burns Wyoming bituminous coal. Apart from the height of the stack and the area of the stack and the flues, all of which on account of the altitude are about 20 percent larger than for normal sea level conditions, this design of the boiler house and the identical apparatus contained therein, is equally applicable to any section of this country where bituminous coal is the economic fuel.

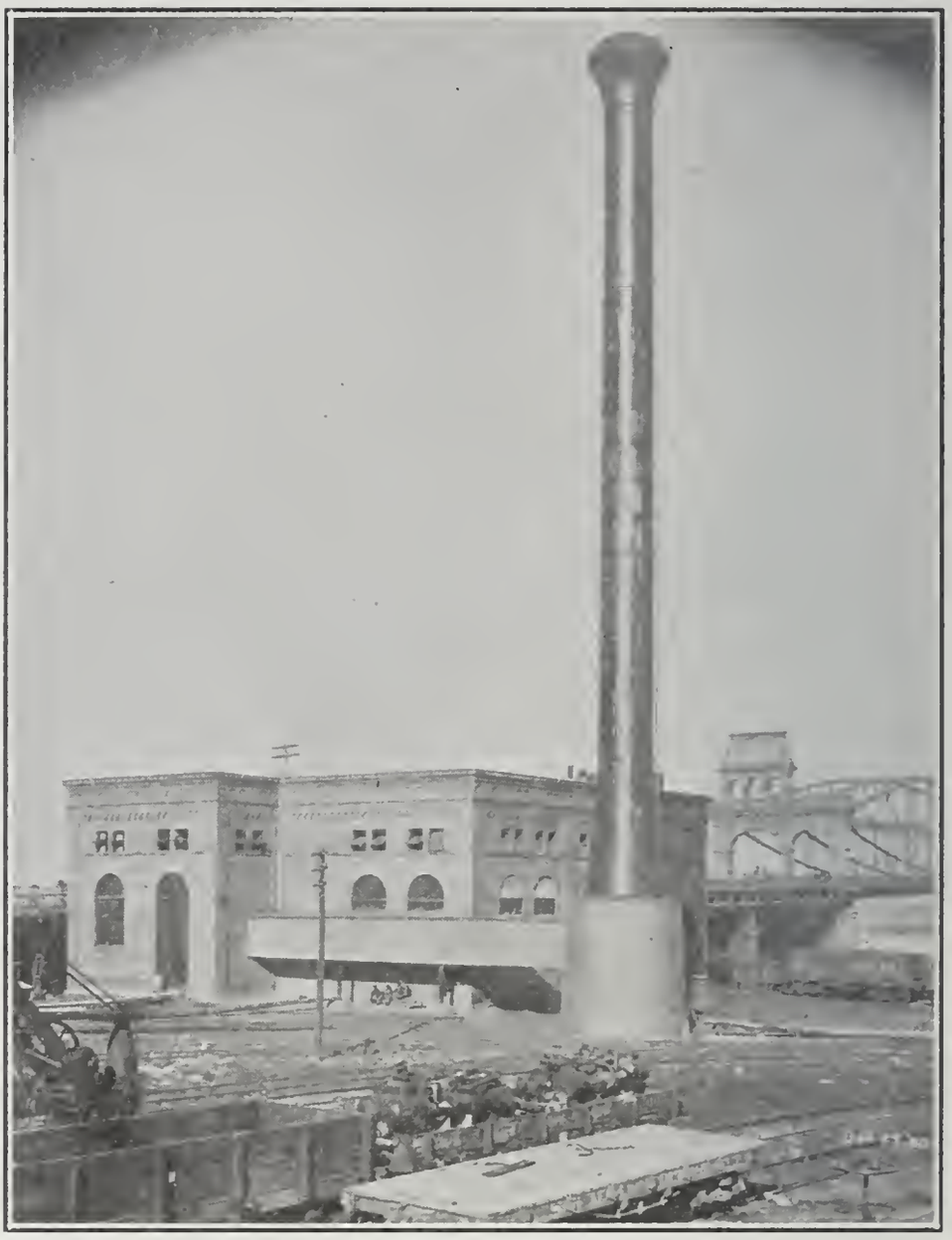

Fig. 10. Pittsburgh & Lake Erie Ry. Co. Power Plant at Pittsburgh Terminal.

You will note there is the overhead coal bunker as the flywheel on the coal supply, the coal in this case being distributed in the bunker by a belt conveyor, and then reaching the stokers by means of gravity spouts.

One main principle underlies the design, construction and operation of all power plants, and this is the requirement that the plant shall produce a given amount of useful power under the conditions imposed for a term of years for the least total cost, including all direct and indirect expenditures. These expenditures include not only the direct operating and maintenance charges, but also fixed charges on the total amount invested in the plant and all costs of interruptions to service that could have been prevented by investment in more or different equipment.

Fig. 11. Hamilton Mfg. Co. Power Plant for Mills at Lowell.

A study of costs is therefore a key to the design of a power plant for any purpose, and this will be the principal topic of this paper. Although the discussion will be limited to steam turbine driven electric plants, many of the considerations affecting the proper design and costs of such plants, are, of course, applicable to steam power plants of all sizes and classes.

Inasmuch as the boiler room end of a steam plant is much the same irrespective of the prime movers, the data relating to boiler room equipment will be generally applicable to all types of stations.

The unit generally used in comparing such plant costs is the kilowatt capacity of the generators installed. As there is today some little confusion in defining the rating of large generators, attention is called particularly to the fact the figures given in this paper are based on the maximum continuous capacity of the generator or the output that the machine will give with a temperature rise not exceeding 50 deg. cent. above the surrounding air temperature.

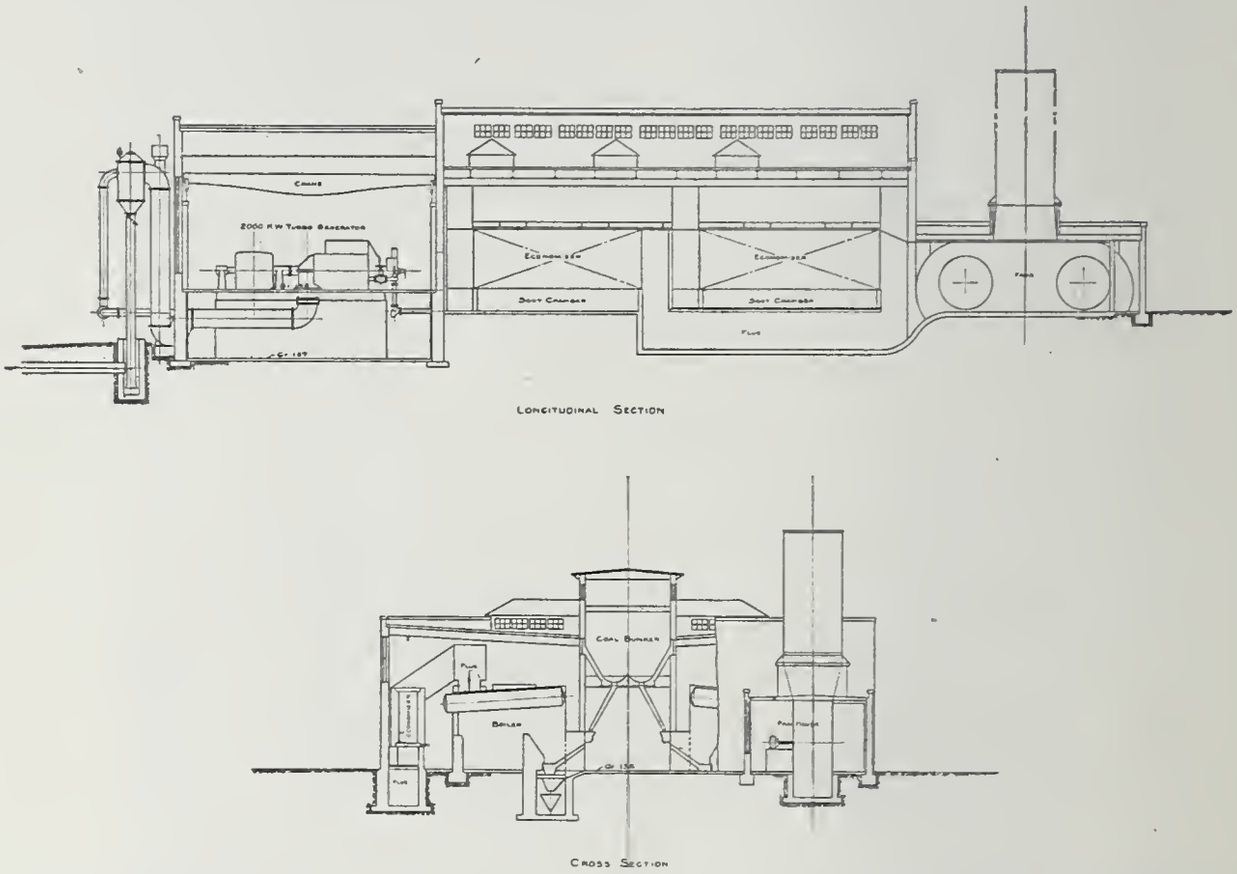

Fig. 12. Northern Colorado Power Company. Cross-sections of Plant.

Table No. 1 shows probable limits of cost of stations of the class referred to, namely steam turbine driven, electric stations for all purposes, using bituminous coal for fuel and having no other equipment in them except that necessary to generate alternating electric current efficiently.

TABLE NO. 1

COST OF STEAM TURBO-ELECTRIC GENERATING STATIONS

From say 2,000 to 20,000 K. W. capacity, based on maximum continuous capacity of Generators at 50 deg. rise.

	DOLLARS PER K. W. High	Low
PREPARING SITE—Dismantling and removing structures from site, making construction roads, tracks, etc.	$ 0.25	$ 0
YARD WORK—Intake and discharge flumes for condensing water, railway siding, grading, fencing sidewalks, etc.	2.50	1.00
FOUNDATIONS—Including foundations for building, stacks and machinery, together with excavation, piling, waterproofing, etc.	6.00	1.00
BUILDING—Including frame, walls, floors, roofs, windows and doors, coal bunker, etc., but exclusive of foundations, heating, plumbing and lighting	12.00	4.00
BOILER ROOM EQUIPMENT—Including boilers, stokers, flues, stacks, feed-pumps, feed-water heater, economizers, mechanical draft and all piping and pipe covering for entire station except condenser water piping	24.00	12.00
TURBINE ROOM EQUIPMENT—Including steam turbines and generators, condensers with condenser auxiliaries and condensing water piping, oiling system, etc	22.00	12.00
ELECTRICAL SWITCHING EQUIPMENT—Including exciters of all kinds, masonry switch structure with all switchboards, switches, instruments, etc., and all wiring except for building lighting	5.00	2.00
SERVICE EQUIPMENT—Such as cranes, lighting, heating, plumbing, fire protection, compressed air, furniture, permanent tools, coal and ash handling machinery, etc., etc.	5.00	2.50
STARTING UP—Labor, fuel and supplies for getting plant ready to carry useful load	1.00	0.50
GENERAL CHARGES—Such as Engineering, Purchasing, Supervision, Clerical Work, Construction Plant & Supplies, Watchmen, Cleaning up, etc., etc	6.00	3.00
Total cost of plant to owner, except land and interest during construction	$83.75	$38.00

Some of the group costs in this table do not have any very specific relation to the kilowatt capacity installed in the plant and the probable range in such costs is a matter of experience with previous cases. This refers to such groups as "Preparing Site", "Yard Work", "Electrical Switching Equipment" and "Service Equipment". For instance, the main item of cost com-

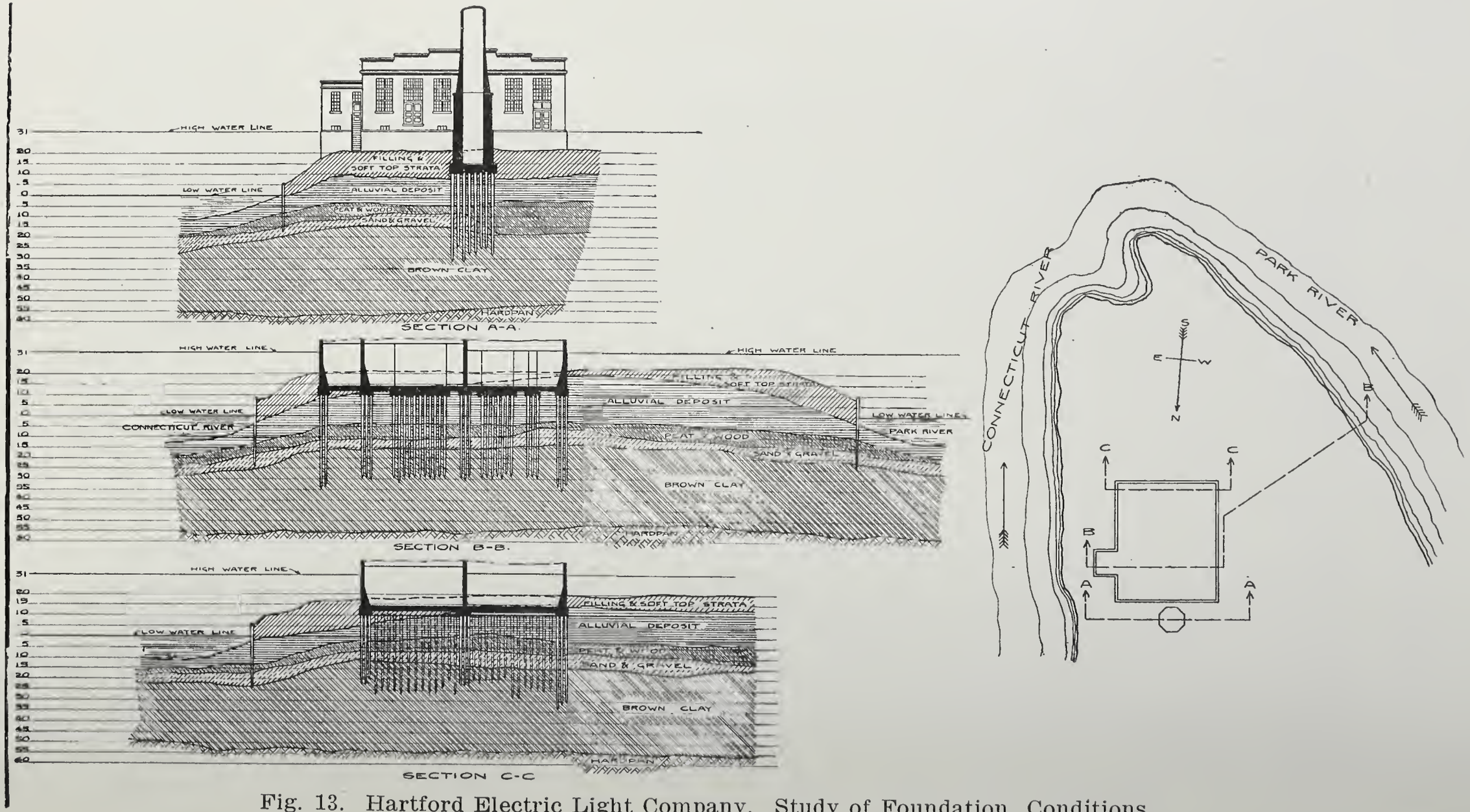

Fig. 13. Hartford Electric Light Company. Study of Foundation Conditions.

ing under the "Yard" group is generally that of condensing water flumes exterior to the building and it will be readily understood that this cost is affected much more by the relative location of the building to the water supply and by the character of work required than by the actual size of the plant.

Similarly the electrical switching equipment costs depend much more on the extent and the scope of the electrical distributing system than upon the actual capacity of the plant. Again the largest item of the "Service Equipment" costs, namely that of coal handling depends upon the existing physical conditions much more than upon the capacity.

Some of these cost groups, however, can be reduced to other units than that of the kilowatt, and this permits a clearer understanding of their range.

The foundation costs, for instance, will run from $1.25 to $4.00 per sq. ft. of building plan area, depending on the character of the soil; the lower cost covering simple concrete footings on thoroughly good bearing soil, while the necessity for piling, waterproofing, excessive rock excavation, etc., will run this cost toward the higher limit. Then the plan area will vary from 0.8 to 1.5 sq. ft. for each kw. of capacity installed, depending upon the size of the units and upon their arrangement; the combined effect of these two cost ranges giving the range in price per kilowatt shown on the table.

The building costs will vary from 8c. to 12c. per cu. ft. of overall building volume, according to the size of the building, and the character of construction and the local price of building materials and labor. Depending again upon the size of the units and upon the efficiency used in arranging them, there will be required from 50 to 100 cu. ft. of volume per kilowatt of capacity. The combined effect is to make the building costs range from $4.00 to $12.00 per kw. as shown.

In boiler room equipment the cost of materials and labor will generally be between $30 and $40 per nominal boiler horse power, and generally there will be installed between 0.4 and 0.6 boiler horse power per kilowatt of capacity, resulting in the cost range shown on the table.

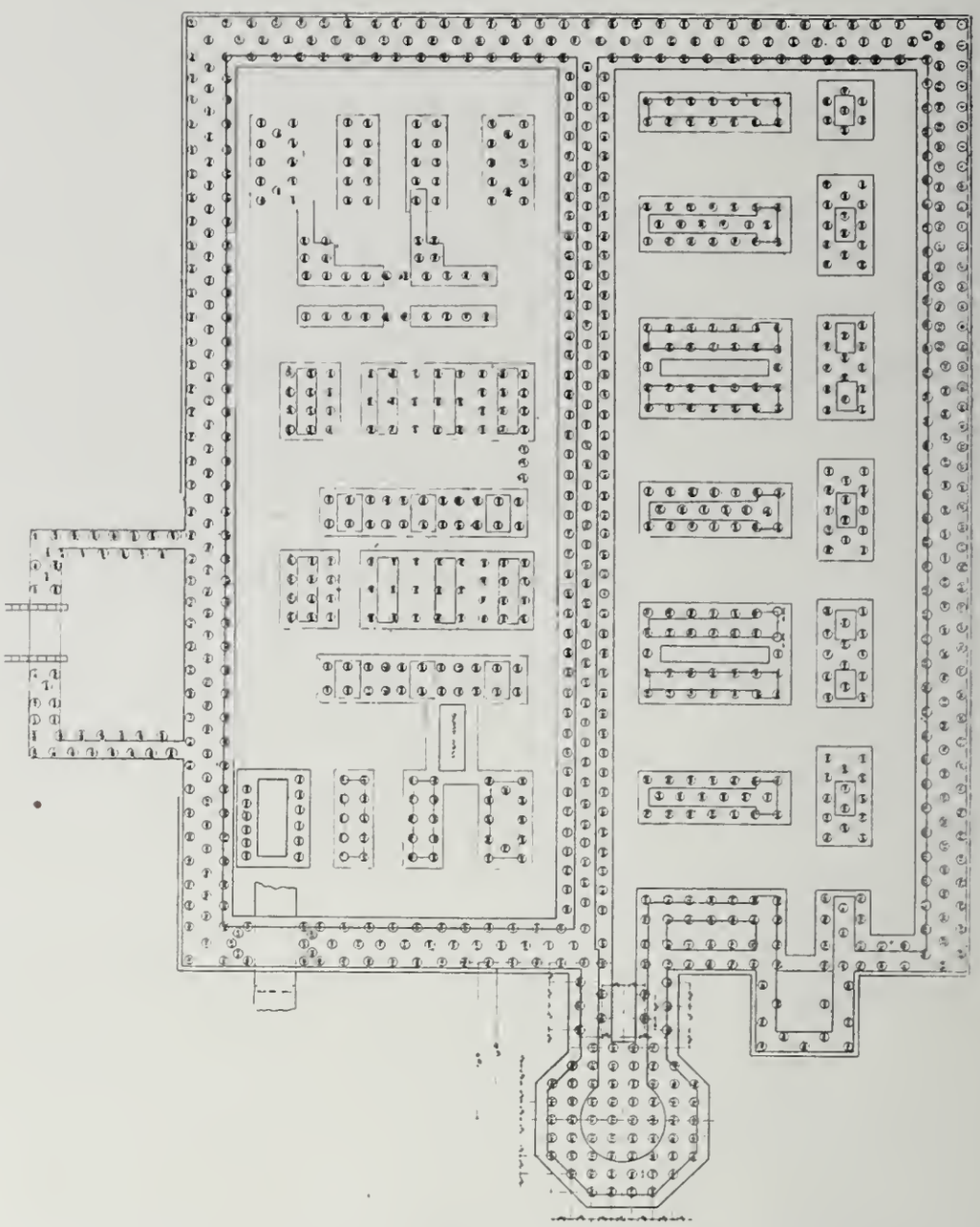

Fig. 14. Hartford Electric Light Company. Diagram of Piling.

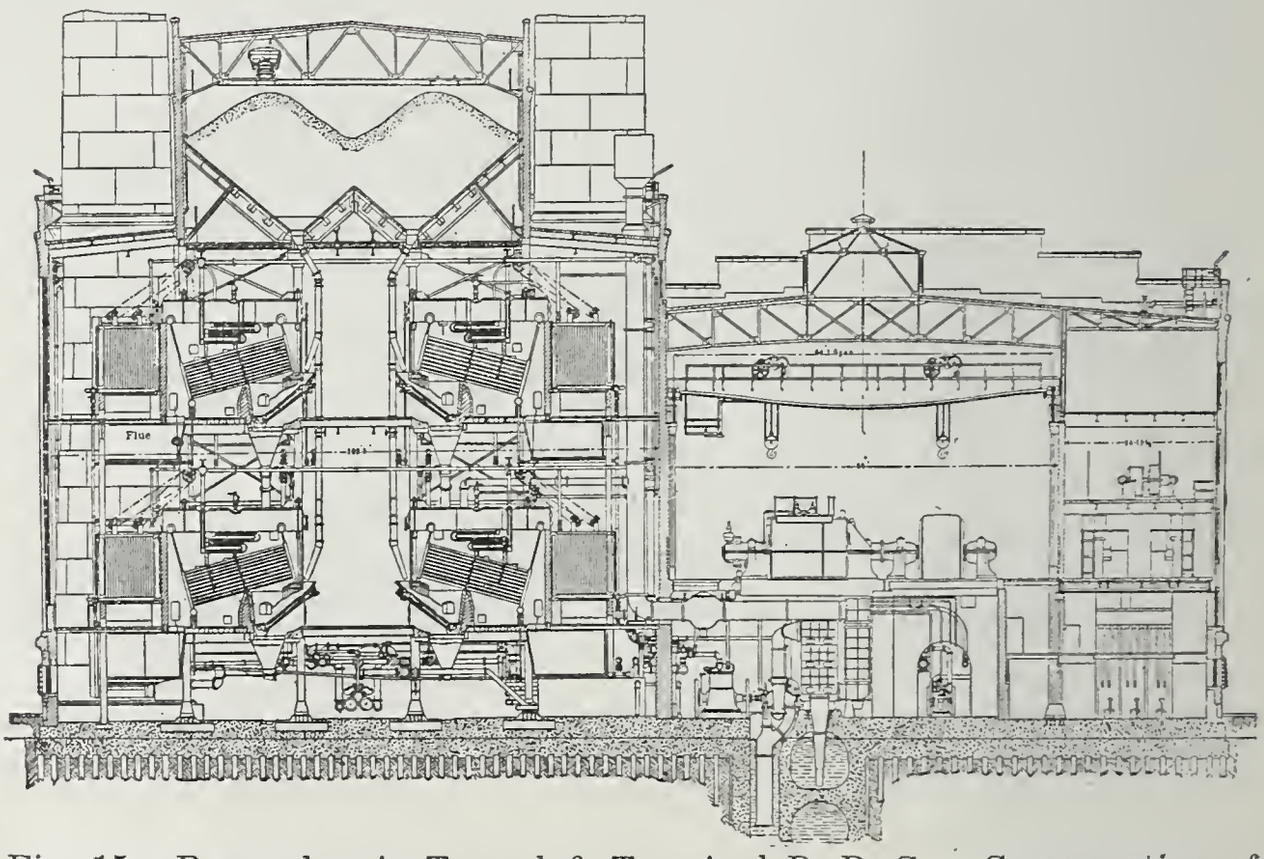

Fig. 15. Pennsylvania Tunnel & Terminal R. R. Co. Cross-section of Long Island City Station.

From this table it is seen that the cost of such stations under normal conditions may range in price from $40 to $85 per kilowatt of maximum continuous generator capacity. So far known to the writers, no stations have as yet been built for the lower figure, for this minimum is possible only with an extremely fortunate combination of circumstances, such as natural advantages of location combined with most favorable sizes and arrangement of apparatus.

It is apparent from this table that there may be a very large difference in the first costs of two stations of the same size, and that this may be the case, even though the two stations have been designed and built with equal ability and economy.

Real Estate: The actual cost of real estate makes practically no difference in design in the very large majority of cases; for, as a general proposition, it may be said that if sufficient room is allowed around the apparatus for its proper operation and maintenance, no material benefit can be obtained by spreading the apparatus over more territory; while on the other hand, such spreading of apparatus invariably increases the cost, particularly that of foundations and building. The cases where real estate is so valuable that the double deck boiler house is desirable, are rare exceptions.

On the other hand, the location with reference to fuel and water supply and the physical condition of the property do very materially affect the cost much more so indeed than any other one factor, except possibly the proportioning and arrangement of the apparatus. It is practically essential for any moderate or large sized power plant that the property have rail connections for the delivery of coal. It is almost essential that there be an ample supply of condensing water, though cooling towers may be used with increased first cost and decreased economy. In the consideration of alternative sites, the cost of the "Yard Work" may have an important bearing.

Rarely indeed, is there a case where the site of a power plant is selected with regard only to the cost of land. If the power plant is attached to an industrial or manufacturing establishment, the site is located with regard to the handling of

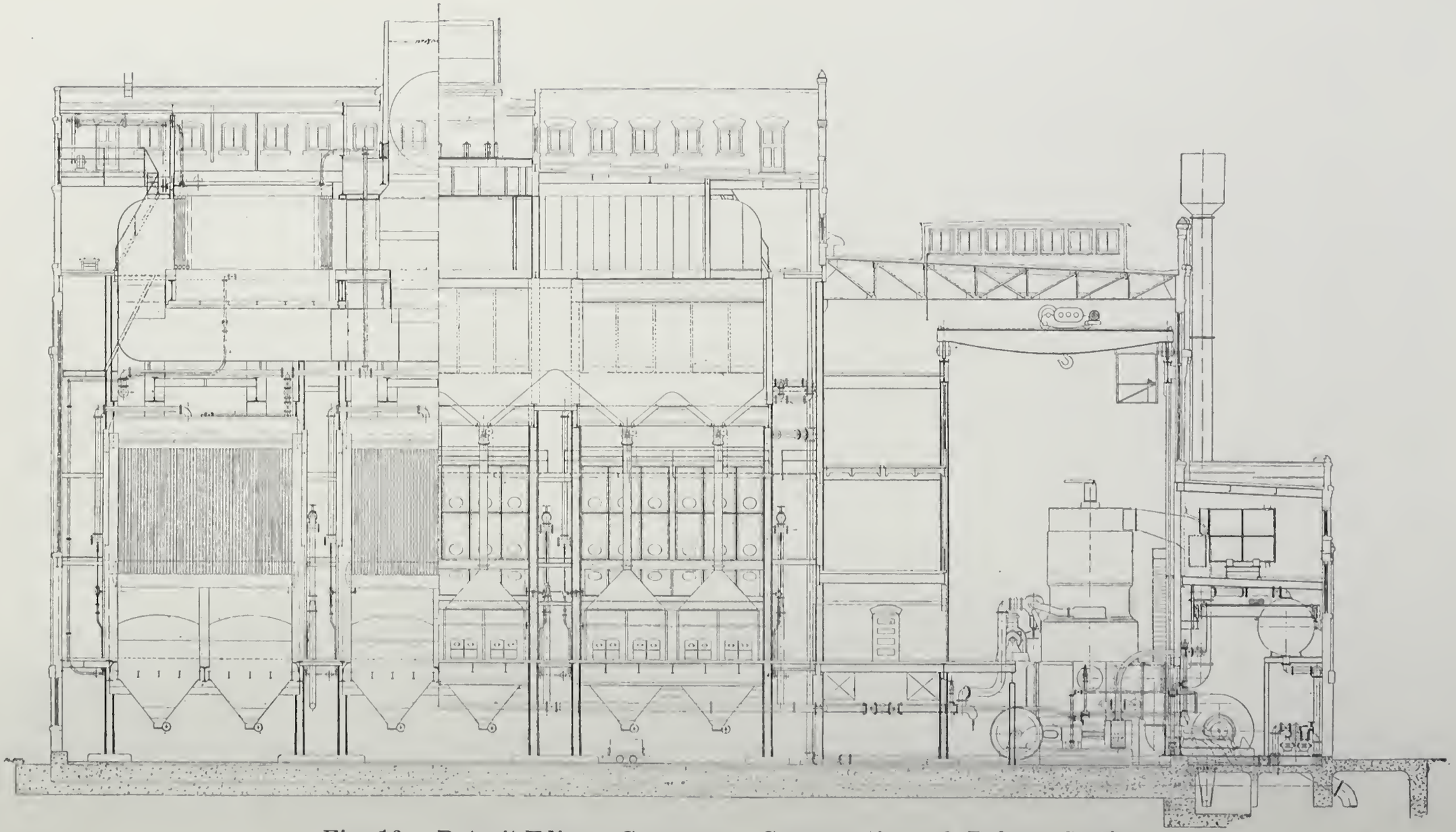

Fig. 16. Detroit-Edison Company. Cross-section of Delray Station.

the raw material and the finished product. In the case of a central plant for light or traction, the power plant site is generally a selection between one or two available sites, and ofttimes is of commercial necessity fixed on a site long predetermined. Consequently, nearly every plant starts with a location which is not quite ideal.

Foundations: The condensing apparatus can only be placed a definite height above the extreme lowest level of the condensing water supply. This alone determines the basement floor level, and, if in flood stages the river rises sufficiently to endanger apparatus at this level, more or less expensive costs are involved in the proper protection of the apparatus.

The bearing value of the soil largely affects the cost, as the necessity for piling under all foundations or the necessity for large rock excavation instead of good bearing soil at suitable level, will increase the cost two or three dollars per kilowatt.

Buildings: The cost of the building is dependent upon the character of the building which it is desirable to erect to be in keeping with the location and with other property of the operating company; but this cost depends much more on the efficiency in design and the proper arrangement and spacing of the apparatus.

With a fortunate size and arrangement of apparatus only 50 cu. ft. of building volume may be required per kilowatt, while with a disadvantageous size of apparatus and with less regard being paid to an economical arrangement as much as 100 cu. ft. often results.

In regard to the cost of finish or style in the architecture of the power plant building, in the majority of cases a plain and simple treatment usually best meets the requirements; but occasionally the location is such that a more ornate treatment harmoniously fits the surroundings.

It is often thought that such special treatment can be obtained only at large extra cost. As a matter of fact, a reasonable amount of ornamentation can be obtained without adding more than five or ten percent to the cost of the building item, or say one percent to the total cost of the plant.

Boiler Room Equipment: The range in the cost of the boiler room equipment is large, but as this item is of especial interest owing to its application in all types of steam plants, it will be the subject of more detail consideration later.

Turbine Room Equipment: In the past few years the steam turbine has been so perfected that wherever generating units of 300 or 400 kilowatts or over are required, it is more desirable than the reciprocating type of prime mover, not because of the economy in fuel, but because the direct first cost of this type of equipment is less than that of the reciprocating type, and the other correlated first costs, such as those of building and foundations are also much less.

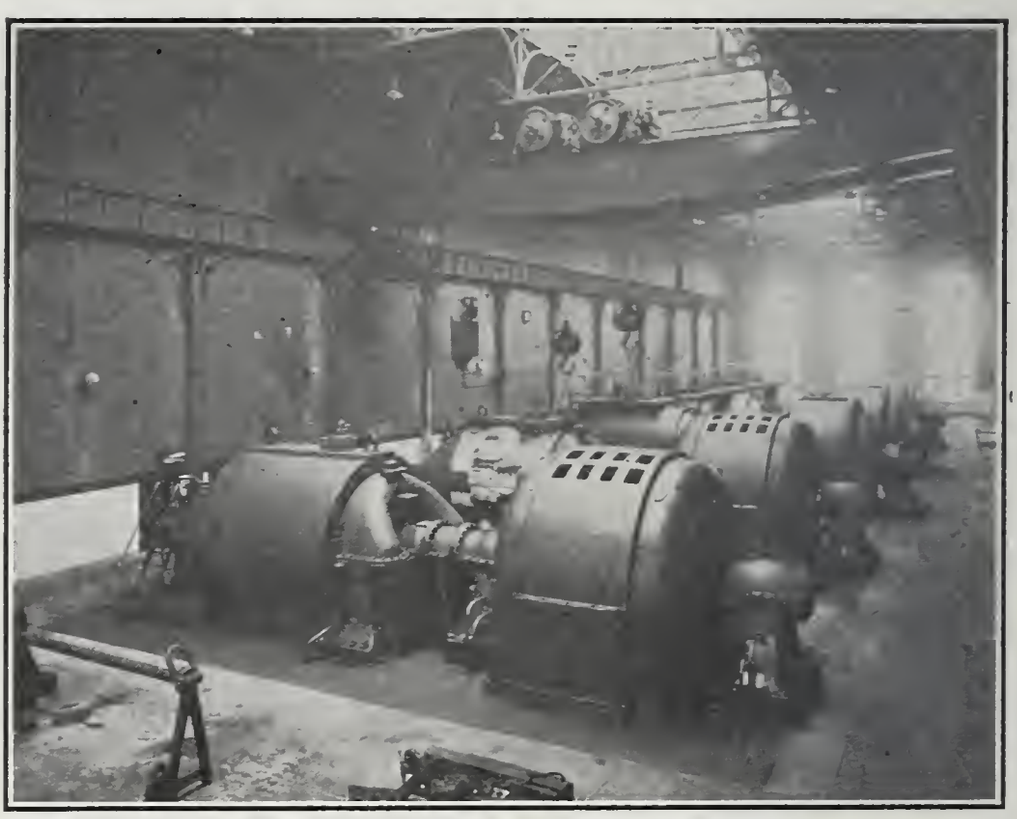

Fig. 17. Pennsylvania Tunnel & Terminal R. R. Co. Turbine Room Long Island City Station.

The cost of the turbine room equipment depends mostly upon the size and the speed of the main generating units. Naturally, the higher the speeds the less the first cost of the apparatus. Units of 2000 kw. and less are now considered practicable with speeds of 3600 r.p.m., whereas the larger sizes run at 1500 or 1800 r.p.m., depending upon the frequency of the electrical system; that is whether 25 or 60 cycles. The factors

entering into this item of cost are generally determined by the existing conditions surrounding the project rather than by the engineer.

In connection with the tendency toward higher turbine speeds, a warning is necessary. The speeds already adopted have, in some cases, been such as to introduce mechanical stresses too close to the safe limits and more conservatism is advisable.

Another factor affecting the costs of the turbine room equipment is the type of condenser selected. Condensers can be divided into two classes, first the surface condenser in which the condensing water does not come in contact with the condensed steam; and second the mixing condenser in which the condensing water and the products of condensation mingle.

As a surface condenser installation will cost from $1.00 to $3.00 a kilowatt more than the mixing type, the warrant for it must be thoroughly established. Following the development of the steam turbine, with which a refinement in vacuum means a much greater saving than with a reciprocating unit, mixing type condensers have been developed to such a point that they can now be relied upon to give fully as good a vacuum as surface condensers. The selection between these two types of condensers depends upon whether or not the supply of condensing water is suitable for feed-water, as if it is suitable, there is no good reason for the surface type. If the condensing water supply is not suitable for feed-water, it is then a question of whether or not the surface condenser saves enough in the cost of feed-water to warrant its greater first cost. As a very general statement, if the cost of feed-water does not exceed six cents per 1 000 gallons; and if the average load on the plant does not exceed ½ the maximum load, then surface condensers are not warranted.

Formerly with reciprocating engines, it was possible to decrease the first cost of a station when its fuel economy was not essential or particularly when used only as a standby plant, by omitting the condensing apparatus. A steam turbine however, takes about 50 to 70 percent more steam when running non-condensing than condensing, and the first cost of providing the extra boiler capacity to run the unit noncondensing is

generally much greater than the cost of the condenser with the necessary flumes for supply and discharge of cooling water. This results in the peculiar condition that a non-condensing turbine plant will not only cost more to operate, but will actually have an equal or greater first cost: In other words, a non-

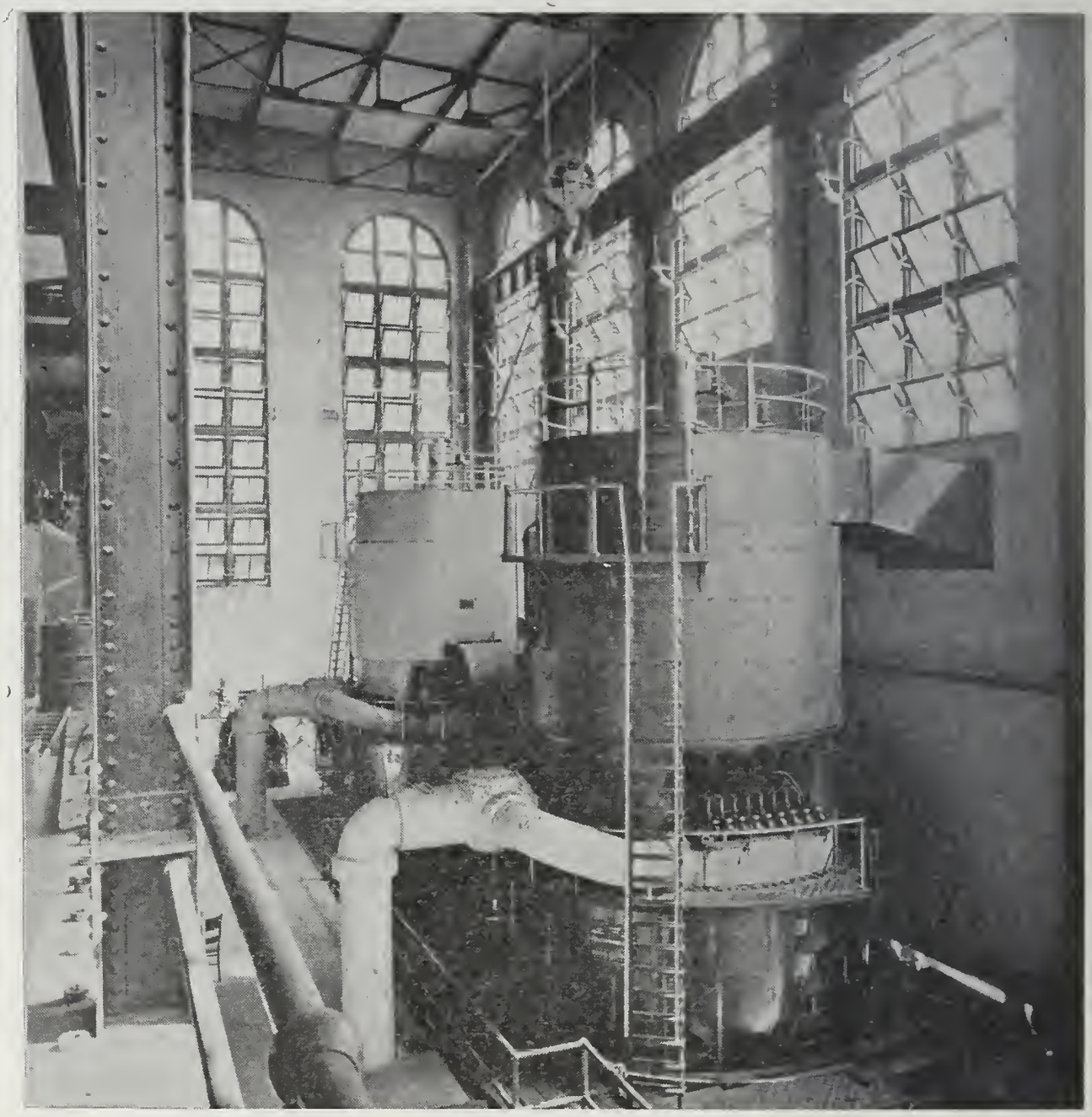

Fig. 18. Detroit-Edison Company. Turbine Room Delray Station.

condensing station is no longer commercially feasible, except, of course, where there is a large requirement of exhaust steam for heating.

Electrical Switching Equipment: The cost of electrical switching equipment does not necessarily vary proportionately

with the size of the plant. It depends more directly upon the character of the service in which the electric current is used.

Service Equipment: In the service equipment the item of coal handling is the largest variable factor affecting the cost. If the plant is so close to the mines that a reasonably continuous supply of fuel can be relied upon, no large outside storage of coal may be necessary, and the supply generally provided for in an inside bunker, may suitably serve as a fly-wheel on the coal supply to the boilers. If the plant is at a considerable distance from the mines, more or less outside storage is desirable.

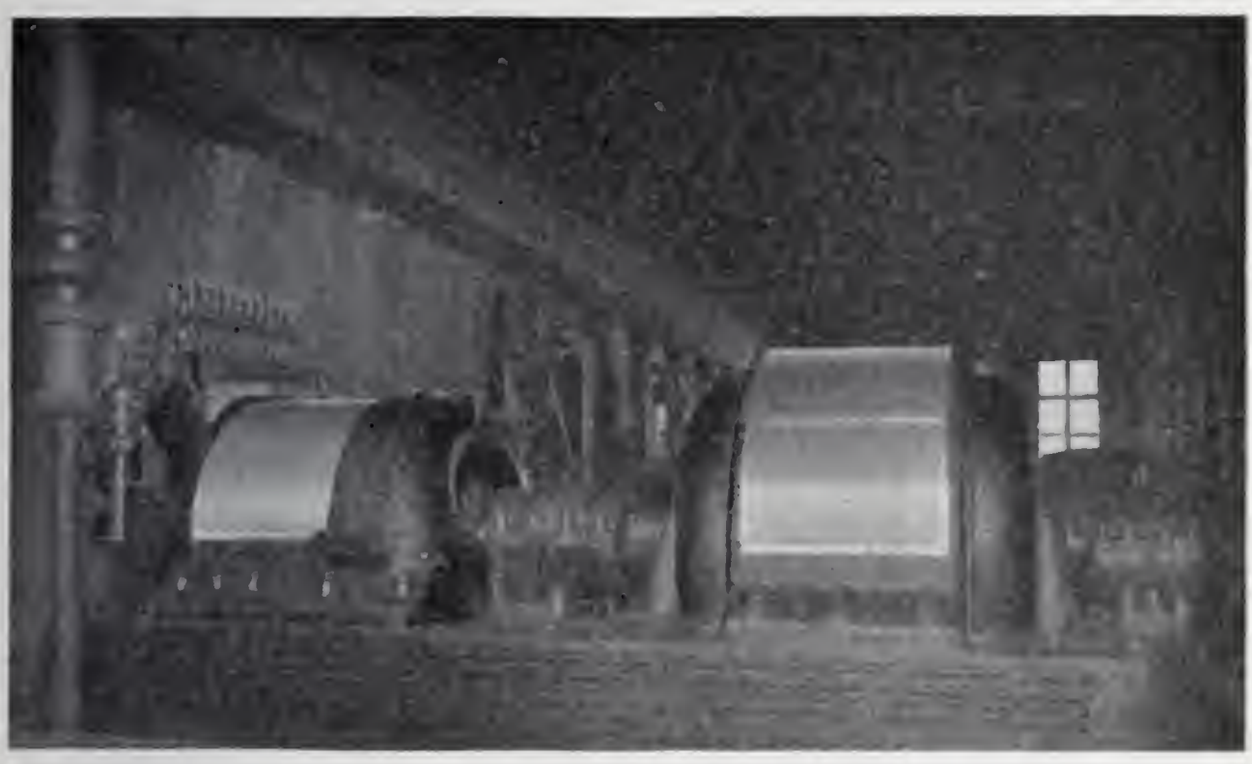

Fig. 19. Hartford Electric Light Company. Turbine Room.

In any event mechanical handling devices are a distinct economy in a moderate or large sized boiler plant, but these devices are so numerous and so different of application that they would require separate treatment to even outline the possible applications. There are several devices which will fit most cases, and the suitability of arrangement depends upon the relative locations and elevations of the side track, the storage pile and the boiler house.

Starting Up and General Charges: The items of starting up and the general charges as shown in the table hardly need any explanation except possibly to say that the item of starting

up is often overlooked during the initial stages of the project, but is usually found when the final costs are added up.

A part of the foregoing items of variable cost in a power plant are determined as soon as the site of the plant is located; others are determined as soon as the load requirements are known, but a large number remain which are dependent upon the experience of the designer and his ability to formulate correctly and judge wisely between the equations of economy on the one hand and of first cost on the other.

Considering now in detail the question of boiler room equipment, the problems of which are involved in all steam power plants, Table No. 2 shows a probable high and low range of costs for this group of apparatus. It will be noticed that the totals here shown cover a wider range than used in preparing Table No. 1 where the price per horse power was taken as from $30 to $40; this is because while the wider range is possible, the costs in generating stations actually lie within the narrower range.

TABLE NO. 2

BOILER ROOM EQUIPMENT COSTS PER RATED BOILER HORSE-POWER; USING COAL FOR FUEL

	DOLLARS PER H. P.	
	High	Low
Boilers exclusive of masonry setting	$11.00	$ 8.00
Superheaters	3.00	0
Stokers	5.50	3.00
Masonry Settings for boilers	3.50	2.00
Flues	1.50	0.75
Stacks	4.00	2.00
Economizers	4.00	0
Mechanical Draft	3.00	0
Feed-Pumps	1.50	0.50
Feed-Heaters	1.00	0.40
All Piping and Pipe Covering	10.00	6.00
Coal Chutes and Ash Hoppers	1.25	0
Various, such as Indicating and Recording Devices, Damper Regulator, Ladders and Runways, Painting, etc., etc.	1.00	0.50
TOTALS	$50.25	$23.15

NOTES:—The above costs are for labor and material only. They do not include any "General Charges" such as Engineering or Supervision. The piping item includes all piping in the entire plant except condenser water piping.

The unit costs in Table No. 2 are related to rated boiler horse power instead of the kilowatt as used in Table No. 1, as these costs vary almost directly with the rating of the boilers, regardless of how much boiler capacity may be installed to serve a given amount of generator capacity. With a given cost per horse power for this boiler room group, the cost per kilowatt will vary according to the proportioning of the boiler capacity to the generator capacity. This proportion is the most important single question in power station design that is subject

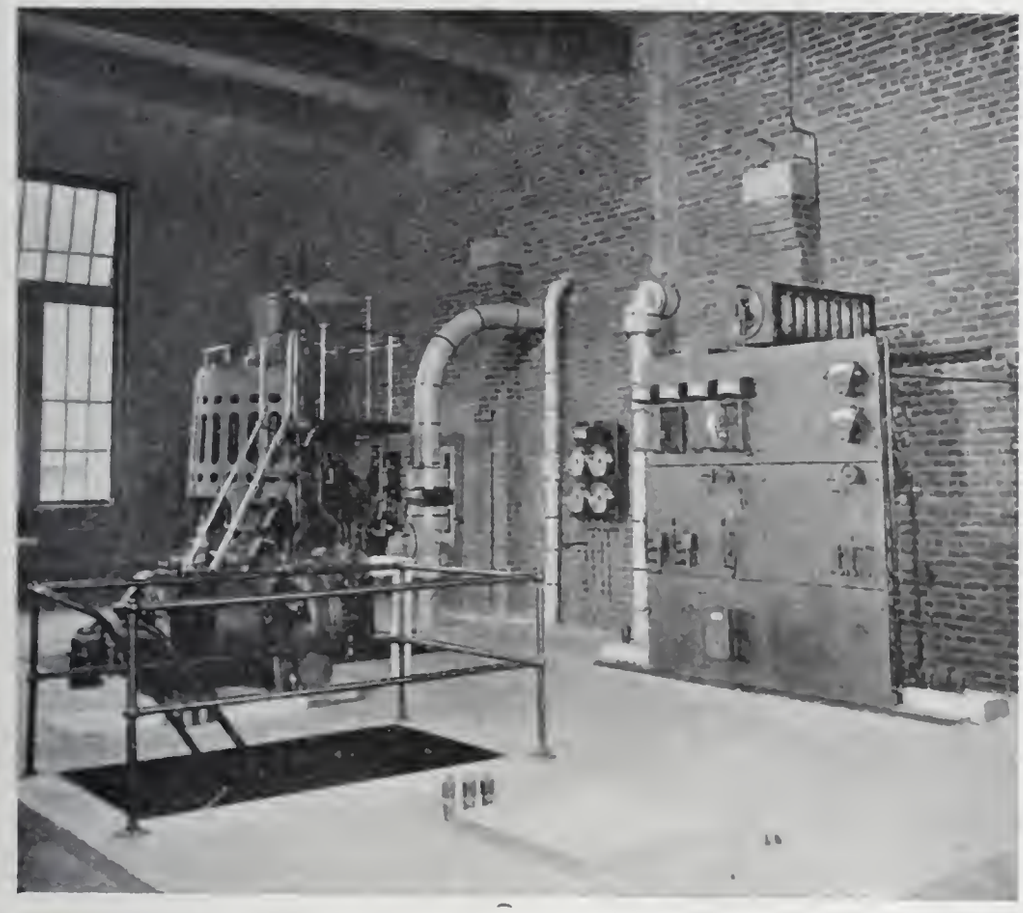

Fig. 20. Central Indiana Lighting Company. Turbine Room.

only to the judgment of the designing engineer and the result of his decision may make a wide variation in the total cost, for it not only directly affects the cost of this boiler room group, but indirectly and very largely affects the items of building, foundations and service equipment.

The argument has at times been advanced that boiler room design depended very largely on the local price of coal. As a matter of fact, with two specific exceptions; namely, superheaters and economizers, (including with the latter their usual con-

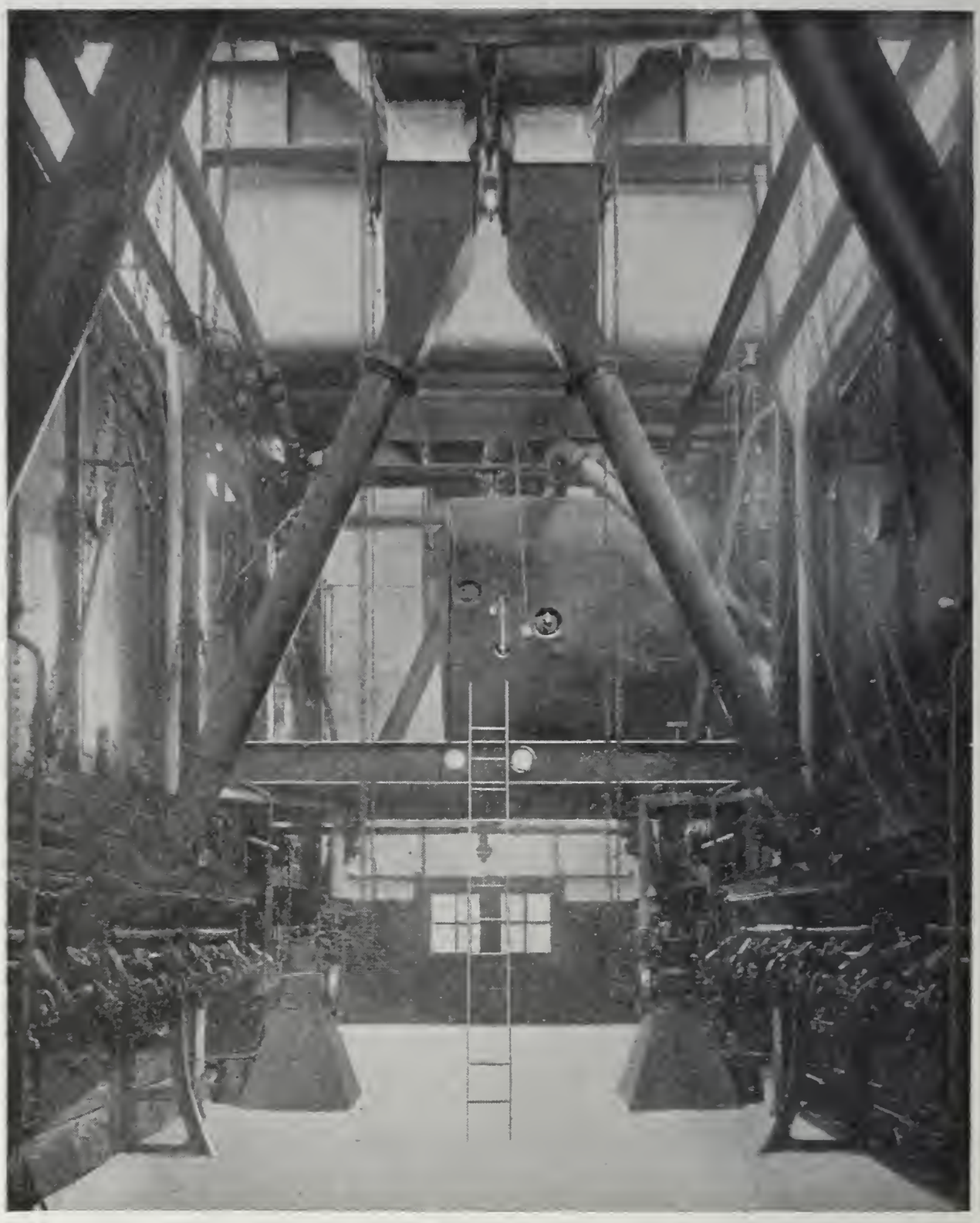

Fig. 21. Utah Light & Railway Company. Boiler Room.

comitant, mechanical draft) the design of a boiler plant should be practically the same with the same kind of coal whether the plant is to be in Pittsburgh where the coal may cost $1.50 per ton, or in New York where the same grade of coal may cost $3.00 per ton.

In other words, the kind and quality of fuel may have some bearing on the proper cost of the boiler room equipment, but when the fuel has been selected, as in this case we have selected

bituminous coal, the only items of first cost of plant which should be materially affected by the cost of this fuel are the economizers and superheaters.

The question of superheat is usually involved only when the main portion of the steam is utilized in steam turbines. When such is the case, the use of superheat ranging from 100 to 150 deg. fahr. will improve the overall fuel efficiency of the plant from five to seven percent; and superheaters will generally result in an overall economy, even with coal as low as $1.50 per ton.

In power plants, other than generating stations, where the steam is not used in turbines, superheat is seldom used.

Economizers have two uses; economy of heat, and heat storage. In general, it may be roughly stated that with 50 percent annual load factor and coal costing $3.00 or more per ton, the saving in heat with the economizers, is enough to more than cover their fixed charges and maintenance. These conditions may vary 20 per cent and the economizers still show an annual saving. When coal costs considerably less than $3.00 per ton, as in the Pittsburgh district, economizers are seldom justified by heat economy only. The advantage of heat storage, on the other hand, often justifies their use irrespective of the price of fuel. With a rapidly fluctuating load, the economizers aid the boilers in meeting sudden demands.

Considering the boilers themselves, there seems to be a decided tendency to use as large units as have been shown to be commercially satisfactory. This has practically resulted from the development of the steam turbine in large units.

There is every incentive from the standpoint of first cost to reduce the number of boilers to the minimum that will meet operating requirements, and therefore to make each boiler unit as large as practicable. This is done at a slight gain of economy, although first cost and not economy is the principal motive. Boiler units of about 600 h. p. each are common practice. Much larger boilers have been installed in a few cases, and the results to date are very promising.

In addition to using larger boiler units, there is also a decided tendency to make a given amount of boiler surface develop more power than formerly.

Many years ago it was defined that 10 sq. ft. of heating surface should constitute one horse power in the rating of a boiler, and with the methods of burning coal then employed, it was only possible to obtain about one horse power from this amount of surface. With the gradual development of mechanical stokers and our greater knowledge of the laws governing the efficient combustion of coal, it is quite practicable to obtain 1½ horse power, or even two horse power from this same 10

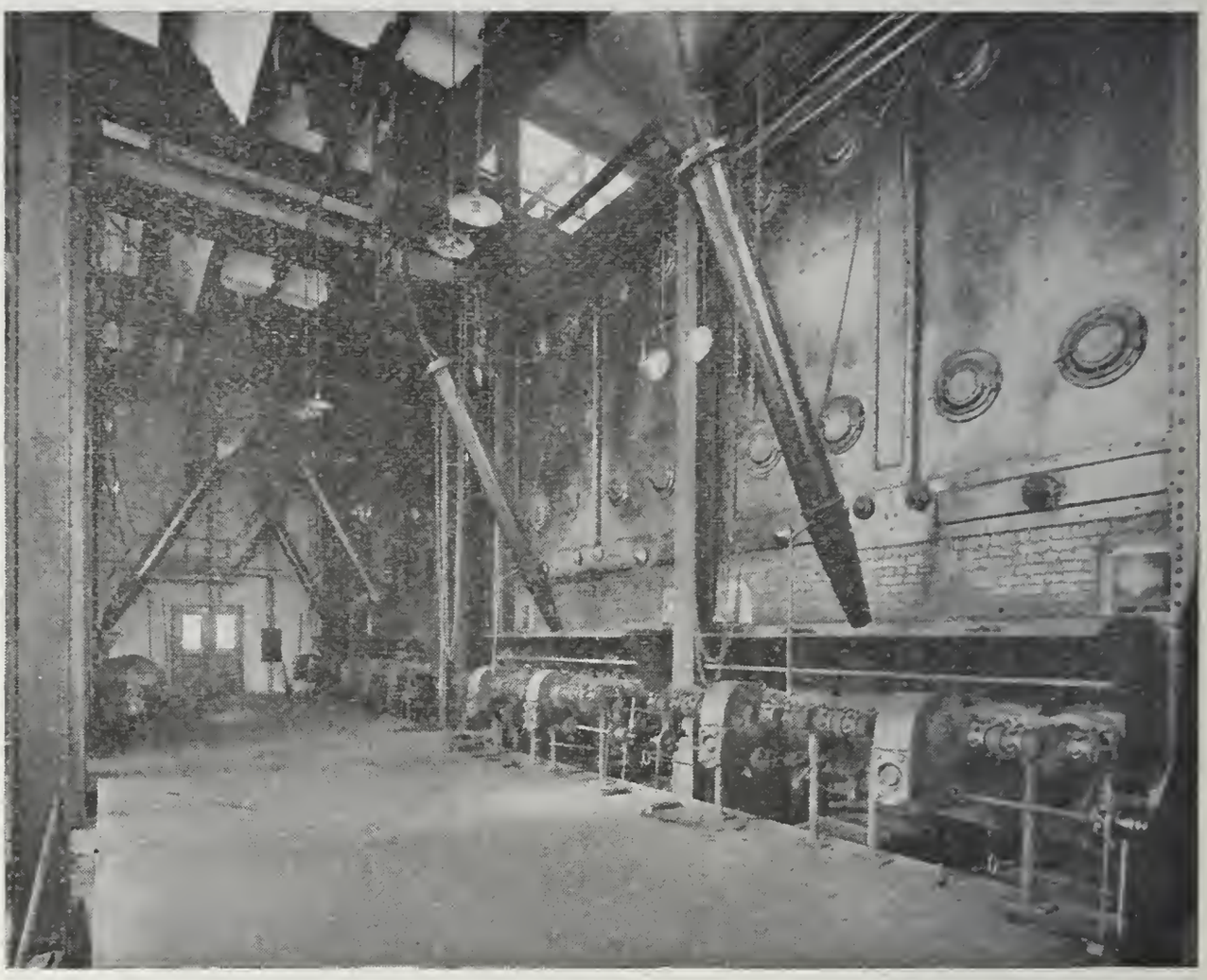

Fig. 22. Worcester Electric Light Company. Boiler Room.

sq. ft. of surface. In other words, it is now customary to demand from boilers at least 150 percent of their rating; and frequently 200 percent.

As the boiler plant must be large enough to supply the maximum demand for steam, it will be seen that if we plan to work the boilers 200 percent of their rating at such times of maximum demand, we have practically cut in half the boiler group costs compared with former conditions.

It is only by the use of mechanical stokers that we can obtain 200 percent from boilers, not because it is impossible to build a boiler under which sufficient hand-fired grate area can be installed to give this overload capacity, but because boilers, as standardized by their manufacturers, are not adaptable to this very large grate area.

Little need be said about the draft apparatus. Natural and not mechanical draft is the general rule. The amount of draft required depends largely upon what maximum overload capacity it has been decided to demand from the boilers. Steel stacks, lined and unlined, brick stacks of radial or common brick and concrete stacks are all satisfactory, and their relative merits and cost are a minor matter. Where economizers are used, the relative advantages of mechanical draft are greater because of the greater draft requirements.

Coming to feed-pumps, the time tried and the time honored, simple reciprocating pump which gave way to the compound steam end reciprocating pump as higher boiler pressures were used, now has a serious rival in the steam turbine-driven centrifugal pump, and this is not for any gain in fuel economy, but because with the small steam turbine now developed into a thoroughly reliable piece of apparatus; and with the cost of the centrifugal unit not much greater than that of the reciprocating unit, the easier operation and cheaper maintenance of the former are winning it consideration.

In the selection of feed-water heaters the "open" type is generally adopted rather than the "closed" type, because it costs less to install and is more readily maintained in an effective condition, besides being more economical in that it returns the condensed water to the system. Formerly "open" heaters were charged with returning oil contained in the exhaust steam to the boilers and thus causing burnt boiler tubes. This was mainly remedied by the development of effective oil separators, and is now dissipated by the adoption of steam turbine-driven auxiliaries, the exhaust from which contains no oil. The main conditions which still leads to the use of the "closed" heater is where the feed-water is not delivered to the plant under sufficient pressure to lift it into the open heater. In such case, it

must be lifted and it is better to do this by the feed-pumps and force it through a closed heater than to pump it twice.

As to the quality of the feed-water, the engineers of this territory are well acquainted with what can be done by means of the lime and soda ash treatment to make otherwise unsatisfactory waters very serviceable indeed, when accompanied by sufficient blowing down of the boilers to keep under control the resulting sulphates carried in solution.

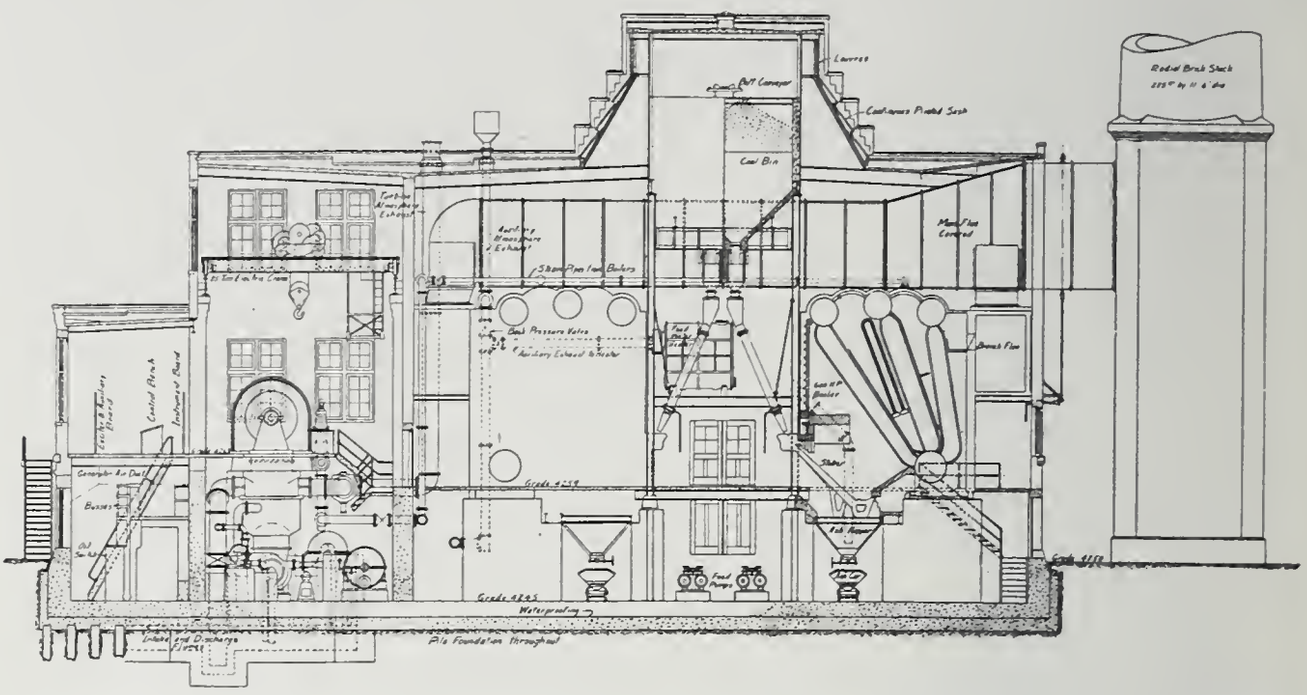

Fig. 23. Utah Light & Railway Company. Cross-section of Jordan Station.

Of piping not much need be said where superheat is not present. The necessity of providing for expansion and contraction of pipes and apparatus is generally well understood, if not always practiced.

With superheaters, however, and particularly with varying amounts of superheat, the usual cast iron fittings and valve bodies have proven unsatisfactory. This is not so much because suitable cast iron mixtures cannot be made, but because generally, they are not yet properly made. As a result, it is generally more satisfactory, even if more costly at first, to use cast steel fittings and cast steel valve bodies, using Monel metal or phosphor bronze for the valve parts.

With the increased boiler pressures and superheat, and particularly with turbines taking steam continuously instead of

intermittently, as with the reciprocating engines there has naturally followed a decrease in pipe sizes. Whereas, formerly an eight inch pipe would be used on a 500 h.p. boiler running not much over rating, a six inch pipe is now used on a 600 h.p. boiler and 1200 h.p. taken through it.

An important feature of steam piping is the pipe covering. Frequently the active competition between manufacturers leads to the use of inadequate covering. Insufficient heat insulation results, as is evident even to the touch, and the covering will not stand the necessary wear and tear. It pays to provide a good covering, well protected and so put together that it may be removed and replaced at small cost where necessary for repairs and adjustment of pipe joints and valves.

Under the heading of Indicating and Recording Devices may be classed Draft Gauges, Recording Thermometers, Gas Sampling and Testing Apparatus, Coal and Water Weighing Devices, etc. These are not refinements. Their combined cost is almost negligible in the total cost of the plant. They are necessary to enable the superintendent to know just what is being done, and if accompanied by intelligent supervision, will, in any large boiler plant, save their cost many times regardless of the price of coal.

TABLE NO. 3

SUMMARY OF OPERATING RESULTS

		Range of Common Practice.
British Thermal Units per pound of fuel	14,000	
Average yearly overall boiler and furnace efficiency	50	70
Effective British Thermal Units per pound of fuel	7,000	9,800
Boiler pressure, pounds per square inch, gauge	125	190
Superheat, degrees Fahrenheit	0	125
Average feed-water temperature, degrees Fahrenheit	120	200
British Thermal Units per pound of steam (approximate)	1,100	1,100
Pounds of water evaporated per pound of fuel, actual	6.36	8.91
Pounds of fuel per standard boiler h. p. (33,305 B. T. U's.)	4.76	3.40
Average overall station water rate K. W.	30	20
Pounds of coal per K. W. generated	4.72	2.25
British Thermal Units in coal per K. W. generated	66,000	31,500
Thermal efficiency of station	5.2%	10.8%

Table No. 3 has been prepared to indicate the range of common practice in coal consumption. Pittsburgh coal of 14 000 B.t.u's per pound is assumed for both cases. The annual av-

erage boiler and furnace efficiency will range from 50 to 70 percent, depending on the nature of the load, the suitability of the station design to this load, and the efficiency of the operating force. Therefore, for each pound of coal burned the B.t.u's made effective in the steam, range from 7000 to 9 800.

Considering next the condition of the water and steam, the boiler pressure may be anything between 125 and 190 lb. In many cases no superheat is used, and in a steam turbine station where the conditions warrant it 125 deg. of superheat may be used. The temperature of the feed-water entering the boiler ordinarily varies between 120 and 200 deg. fahr. These conditions of boiler pressure, superheat and feed-water temperatures may vary in an actual station more than the limits here shown; but the interesting thing is that the combination assumed for the two extremes result in the same number of B.t.u's per pound of steam. The explanation for this lies in the relative temperatures of the feed-water. The additional heat necessary to bring the temperatures of the feed-water of the one case up to that of the other, is enough to raise the steam pressure in the second case to 65 lb. above the first and to superheat the steam 125 deg. The steam in the second case will do ten percent more useful work than the steam in the first case. The importance of proper feed-water heating is apparent.

The combination of the figures in the third line and the seventh line results in those of the eighth line, so that the pounds of water evaporated per pound of fuel varies between 6.36 and 8.91.

Experience has shown that the average annual water rate of such stations, including the main units and all auxiliaries, varies between 30 and 20 lb. per kw.hr. These figures divided by the rate of evaporation, give the figures in the next line for pounds of coal per kilowatt hour generated. These figures in turn multiplied by 14 000, give the B.t.u's in the fuel per kilowatt hour generated, these being average figures for the entire year. A kilowatt hour is theoretically equivalent to 3 420 B.t.u's. Therefore, the annual thermal efficiency of the station may vary between 5.2 percent and 10.8 percent. In other words, one sta-

tion may require more than twice the coal per kilowatt hour per annum as another, even though both are condensing stations operated under conditions within the range of common practice.

Better overall results than the best here shown have been obtained for months at a time, if not years, but these have been cases of particularly large stations or exceptionally good load factors, and it is not often the combination of conditions permits present day apparatus to exceed the high figure here shown.

On the other hand, many power plants do not get even as good results as the lowest in the table. In many cases this is logically due to the small size of the plant or the character of the load, but in some cases it is due to improper design, and in many cases the poor results are due to lack of supervision and knowledge on the part of the operating force.

SUMMARY

In conclusion, therefore, the principal points which we wish to make are:

First: A conventional power station design generally adaptable to a given class of service, is not practicable.

Second: Geographic location, in itself, should have no bearing on the design of a power station.

Third: The location with reference to fuel and water supply and the physical condition of the property, however, have a very important bearing on the cost.

Fourth: The cost of real estate in a large majority of cases has little to do with the design of a power plant. There is small difference between the area that will give sufficient clearances, and the minimum on which the apparatus could be placed. As between two possible sites the costs to be equated against real estate are mostly in the intake and discharge flumes and the coal handling facilities outside the power house.

Fifth: Ornamentation of a power station building to suit local conditions need not add greatly to the cost.

DISCUSSION

Mr. J. N. Chester:* It was stated that recent developments in mixing condensers had brought them up to the efficiency of surface condensers. That applies, I suppose, to the so-called elevated condensers, or does it apply to condensers brought down in close proximity to the turbine?

Mr. O. S. Lyford, Jr.: That applies to quite a number of recent forms of jet condensers, whether barometric or otherwise. As a matter of fact in turbine practice the so-called "low down" forms of condensers are generally favored because they go underneath the turbine and save in the cost of piping and make it easier to maintain a high vacuum because there are less joints to be kept in order.

Mr. J. N. Chester: Any other jet condenser that would go under the turbine and so shorten the exhaust pipe and cut down the friction would do as well, that is for that type of condenser?

Mr. O. S. Lyford, Jr.: Substantially as well.

Mr. J. N. Chester: Could you tell what loss you have between the condenser and the turbine, or in the exhaust pipe? It is generally necessary to provide at least 35 or 40 ft. of exhaust pipe, and ordinarily twice that much with barometic condensers.

Mr. O. S. Lyford, Jr.: Both types of jet condensers are used in the stations described, but I have not the comparative operating figures so that I cannot answer that question.

Mr. J. N. Chester: If turbines were not employed it would seem that superheat was not employed. This might apply of course to electric generating, to which the paper is confined, but in a broader sense the statement would be misleading, for in our slow moving pumping machinery, for instance, and lower duty machines, not high speed, it must be conceded that superheat might materially improve even to a greater extent than as applied to turbines.

I was struck with the comparison of the boilers, the cost

*Consulting Engineer, Union Bank Building, Pittsburgh.

running from $11 to $8, while the cost of piping is rated at $10 to $6, or only $1 less than the boiler installation in the maximum and $2 in the minimum. And it was further stated that this cost of piping did not include those relating to the condenser, I presume, the exhaust, the injection and the tail water pipes. From my own practice these piping figures seem rather high, and some estimates outstanding that I have made will fall short of that statement.

Mr. S. A. Taylor:* In one of the tables the average of Pittsburgh coal is given as 14 000 B.t.u. That would probably be correct for selected lump coal; but for fine coal or slack I think that is rather high.

Dr. Walther Riddle: That point was not specified, was it, about the particular kind of coal?

Mr. O. S. Lyford, Jr.: No, we simply took 14 000 B.t.u. as a good figure to use for illustration.

Mr. P. M. Lincoln:† I would like to ask Mr. Lyford what his experience has shown as the best method of taking care of the varying load factors to which practically all plants are subjected. We all know that during different hours of the day, all plants have different loads to be carried; and also there is a yearly fluctuation which is superposed. Take a plant supplying for instance railways and electric lights, the summer load will be as low as 50 or 60 percent of the winter load, and the load during the early morning hours will be as low as 40 to 60 percent, or even lower, of the load at five o'clock in the afternoon.

What features of design in the power plant have been made to carry this varying load factor to the best advantage? It is of course patent that an apparatus running at full load is at maximum efficiency and as you go above, or below, that load the efficiency drops off. How to design your power plant in order best to take care of such changes of load, is a point on which a great deal of stress can properly be laid.

*Mining Engineer, Lewis Building, Pittsburgh.

†General Engineer, Westinghouse Electric and Mfg. Co., East Pittsburgh.

Mr. O. S. Lyford, Jr.: We have a very interesting illustration in answer to that question. The Utah station was built as a relay for water power and its annual load factor was expected to be very low, and obviously the natural inclination was to cut out all the frills and to introduce only those elements that would enable us to carry the load without much reference to economy. But when we came to work out the design we found that because in a stream turbine installation the condensing proposition is as cheap as, or cheaper in the first cost, than a non-condensing proposition, condensers should obviously be used, and there could really be very little difference in the first cost of such a turbine station, as compared with one designed especially for economy—the only items you can omit to advantage are the economizer and the superheaters. It might be assumed that the coal handling apparatus, and stokers, could be omitted, but you cannot get the capacity out of the boilers without the stoker. With a first class, intelligently designed, steam turbine station there is, therefore, not much that can be done to vary the cost according to whether the load factor is low or high.

Mr. P. M. Lincoln: In connection with that Utah station, it occurred to me while Mr. Lyford was describing it that the station was not very well adapted for the condition which has been described. If it was to take care of a varying load factor it seems to me that the single unit with which that station was equipped would not appear to be the proper design. It seems to me it should have a station with a larger number of units so that the load upon those units could be made to nearly match full load conditions, whereas with a single unit station such as the Utah station, there must be thrown upon that single unit very wide variations of load and necessarily a reduction in the economy, at overload points as well as at reduced load points.

Mr. O. S. Lyford, Jr.: The Utah station relays a number of long distance transmission lines, and the size of this unit was selected with reference to the load that would be dropped in case of trouble on a transmission line or a group of lines. There was a line 126 miles long from one of the Telluride plants and that load was about from 5000 to 6000 k.w. There was another line

that carried the load of three water power stations, and that was about 5000 or 6000 kw. And finally the principal service that had to be maintained irrespective of what happens, is about 5000 or 6000 k.w., so we designed the first section of the station to carry a load between 5000 and 8500 k.w. But there is further expectation, based on the experience of the increase in load, that a 6000 to 8500 k.w. unit will be the natural unit to add as the load increases, this increase being at the rate of 13 to 15 percent per annum. That will be the desirable unit a few years hence to have added every year or two.

Mr. W. A. Bole:* It seems to me that Mr. Lyford might have pointed out the fact that the type of engine employed, viz. the steam turbine, is one of the important elements in the answering of Mr. Lincoln's question regarding economy under varying loads.

It is of course true, as in all steam prime movers, that the turbine engine has a load point of maximum efficiency with a lessening of efficiency at loads either greater or smaller; yet the steam turbine's characteristic in this respect is much more favorable and the loss due to drop in load in the turbine is much less than it is in the reciprocating type of engine.

Mr. Frederick Darlington:‡ I would like to ask Mr. Lyford a question in regard to the changes that should be made in power plant design in case you are building a station where fuel oil is used in place of coal, whether there would be any consideration that might lead to an entirely different type of station. Especially, are there conditions where internal combustion engines should be used where fuel oil reaches a certain price, say $1 a barrel more or less. I would like especially to have him talk on this point with regard to stations of the ordinary size, not going to the extraordinarily large 20 000 or 30 000 k.w. stations, but from 3 000 to 10 000 k.w. as the maximum.

Mr. O. S. Lyford, Jr.: I do not know that I understand just what Mr. Darlington has in mind. Obviously if you are

*Consulting Engineer, The Westinghouse Machine Company, East Pittsburgh.

‡Electrical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh.

going to build a station for fuel oil, you would not provide coal stokers and coal handling equipment.

MR. FREDERICK DARLINGTON: Would you use an internal combustion engine or would you use turbines?

MR. O. S. LYFORD, JR.: That depends on local conditions. Diesel engines are now being built in large units abroad, but such sizes have not been used in this country, and I would go a little slowly in their use.

As far as the station capacity is concerned, we tried to point out that between 2000 and 20 000 k.w. the limits of cost per kilowatt are practically the same and a large station may have certain features that run the cost away up as compared with a smaller station.

MR. J. N. CHESTER: In regard to stokers, while your paper brought the k.w. down to only 1000, which includes a range of good economy in the use of the stoker, if you were asked to extend that range downward, how far would it go and still be consistent with stoker installation?

MR. O. S. LYFORD, JR.: We do not use stokers in the 1000 k.w. station at Columbus, and I doubt very much whether we could have shown much of an advantage there. For one reason or another, it is not customary to force the boilers quite so hard in a small station, and that has some bearing on the use of stokers. I do not think a general answer is immediately available to that question.

MR. E. D. LELAND:* I would like to ask Mr. Lyford if he will tell us why steam turbine installations were selected in preference to producer gas engine units of from 1000 to 2000 k.w.?

In view of the excellent results said to have been obtained at Gary, Indiana, with the large blast furnace gas engines installed there, it is interesting to know why turbines are preferred.

MR. O. S. LYFORD, JR.: That answer would depend on the size of the station largely. In connection with the Utah station

*Superintendent of Compressing Stations, The Philadelphia Company, Pittsburgh.

we considered that question, because there is available within a few miles of Salt Lake City, a large supply of lignite coal that our client at first felt ought to be used in a producer and gas engine plant. But we found in that case that whereas the steam turbine cost in the neighborhood of $60 per k.w., and we could get an ample power station capacity in the area that was available, the gas engine installation, as I remember it, cost about $130 at the maximum rated capacity or more than twice as much, and as a stand-by station that put it out of the running, because of the fixed charges. But we also found that unless the average load factor was about 50 percent and unless the cost of coal was at least $3 a ton, the steam turbine was a better proposition in annual operating cost. That is, the economy of the gas engine did not win out until you got to a price of coal of at least $3 a ton and a high load factor.

Prof. C. L. W. Trinks:* I teach power plant design every Tuesday night and had hoped that I would get out of saying anything this evening, but since our Chairman has called on me, I suppose that I will have to relieve myself of some points.

First, I wish to answer Mr. Chester with regard to the question whether the low type or the elevated type of condenser is better. As nearly as I have been able to figure out, it is about a stand off for this reason: In the elevated type (barometric condenser) the work of pumping the water into the condenser is small, because the vacuum in the vessel helps to lift the water. No work is required to pump the water out, because it runs out. In the low type the water runs in, true enough, but it runs in so fast that it must be throttled, and then it must be pumped out against the full head of the atmosphere. On the question of work for pumping water the elevated condenser is therefore ahead. But this advantage is coupled with the disadvantage of greater distance from the engine or turbine which means that for equal sizes of exhaust piping there is a greater pressure drop (between the turbine exhaust and the condenser vessel) with the elevated type than is found in the low type. Of course, the exhaust pipe may be made quite large and the pres-

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sure drop may thereby be reduced unless questions of cost forbid. Thus it will be seen that the difference in the cost of operations is small with the odds somewhat in favor of a properly designed and properly installed barometric condenser.

Mr. J. N. Chester: Will you tell me of some plants that have elevated barometric condensers that are producing 28½ and 29 in. at the turbine?

Prof. C. L. W. Trinks: Upon inquiry I find that among others the following installations of barometric condensers give 28 in. of vacuum at the turbine: American Iron & Steel Mfg. Co. at Lebanon, Pa., Philadelphia Electric Company, Christian Street Station, Philadelphia, Pa. (both of these condensers are of the Southwark-Weiss type). Youngstown Sheet & Tube Co. vacuum is 28 in. a few feet from exhaust flange of turbine (Mesta-Helander condenser). Mr. A. L. Hoerr† wrote in response to an inquiry: "Our equipment consists of one low pressure turbine driving a 3750 k.w. alternator, 80 percent power factor A. C. generator. The turbine is connected to a Weiss Barometric Condenser by a 63 in. diameter cast iron pipe which is 58 ft. 8 in. long from turbine flange to condenser flange, measured on the center line. When carrying full load on the turbine we were able to maintain a vacuum within one inch of the barometer at the condenser head, and about ⅛ inch less than this at the turbine."

The trouble with many barometric condensers does not lie with the barometric principle, but with a wrong design of the baffles and with insufficient air pump capacity.

Coming to the paper itself, I can only say that it is admirable, but nevertheless I find a few things to criticize. First, I do not quite agree with the statement that geographical location has no influence. I know of a coal mine in this district where the power plant burns the poorest coal found in that mine. Under the circumstances no mechanical stoker can be used, the variation in the slate is so great that hand stoking must be resorted to.

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Furthermore, I miss the subject of feed water treatment. All along the Monongahela River and at many coal mines located along small creeks, treatment of the feed water is a necessity. This fact also preaches that geographical location cannot be neglected.

Finally, I cannot endorse the statement that the steam turbine is the only right prime mover for the modern power plant. If the authors had said that the steam turbine is the right prime mover for power plants as they are located now, I would agree with them, but I do think that most of our modern power plants are not properly located. Relying upon the efficiency of modern alternating current power transmission, engineers have located power plants with regard to cheapness of fuel transmission, cheapness of real estate and convenience of water supply. Now, it always looks like a reckless waste to me to dump 60 percent of the heat of the coal into a river, where it does nobody any good, not even the fish. If the power plants were located nearer the centers of population a great deal of the exhaust heat could be used for home warming. This arrangement is, for instance, used in this building which receives its light, heat and power from a block central station. Wherever exhaust heat can be used, the non-condensing steam power plant goes way ahead in economy of the condensing station. And when steam prime movers run non-condensing, the reciprocating engine is more economical than the turbine. Thus we find reciprocating engines in the block central station near this building.

Perhaps the cost of getting an exhaust-heating franchise through a city council is at present greater than the waste of fuel, but the rising price of fuel will bring about changes.

Finally, it has been mentioned that high superheat is beneficial to turbines only and not to engines. This is correct if by engines we mean the standard American Corliss engine. But if we look at Swiss and German poppet-valve engines or at Belgian piston-valve engines, we find that high superheat, higher than ever used in any turbine, is very beneficial. We find that those engines use less steam than the best steam turbines ever did. And quite recently the Stumpf-cycle engine has stirred up

people considerably, because it uses eleven pounds of steam per i. h. p. hour on saturated steam and less than nine pounds on highly superheated steam. If we also consider the difficulties of making direct current with steam turbines, it appears that the reciprocating engine will continue to live for quite some time.

These are a few things which I thought were worth mentioning. I also feel that we should be thankful to the authors for giving us reliable data on the cost of power plants, because few data of that kind are available.

Mr. W. A. Bole: I hope Prof. Trinks will include in his printed discussion a description of that single cylinder engine that develops a horse power on nine pounds of steam.

Prof. C. L. W. Trinks: Mr. Stumpf has published a book called "Die Gleichstromdampfmaschine" from which the desired information may be obtained. There are also valuable papers in the German publication the "Zeitschrift des Verein Deutscher Ingenieure" of June, October and November, 1911, giving detailed account of the steam economy of the Belgian and German engines.

Some few months ago I saw reports of tests of air pumps on Le Blanc condensers made in Europe. These tests showed that the average efficiency of that pump when referred to isothermal compression was only about eight percent and in an improved type occasionally reached 14 percent. As far as I know no tests of the power consumption of the Westinghouse-Leblanc air pump have ever been published, and the engineering fraternity certainly would like to see reports of such tests merely for the purpose of knowing the present state of the art.

Mr. J. N. Chester: I did not intend to champion any type of condenser or to go to the denfense of any kind. I was in at the birth of the elevated or barometric condenser and I have been interested in the development of that tpye of mixing condenser although I long since lost my financial interest in it.

My definition of a condenser might be illustrated with a story. Passing one day through a steel mill near Pittsburgh where they had recently installed a mixing condenser of the

barometric type, with my old interest I asked what led them to the purchase of that type. They said it was guaranteed to operate with half the water of any other make. I told them that if in any one of half a dozen similar makes of condensers they introduced the same amount of steam and water and mixed them properly and furnished means of removing the air they would obtain about the same result, and I did not believe that anybody had a cinch on vacuum.

So far as the make of condenser is concerned, my questions were not intended to lead in that direction at all. I believe there are half a dozen condensers just as good as the LeBlanc, whether low down or high up. But what does interest me is whether or not the high up condenser, the barometric, where we removed the water by the barometric pressure, is adapted to this high vacuum requirement on account of the long exhaust necessary, of course creating friction and the possibility of leaks. And beside that when you get the extreme vacuum of 28 or 29 inches you have got to have extra large pipes to carry it to the condenser with minimum loss. And whether or not the barometric condenser is practicable where you require the high vacuums of 28 and 29 in. was the point I desire to draw out, and not whether one make of condenser or another would do. I would not like in my remarks to exploit one condenser over another.

Mr. J. A. Hunter:* I did not notice in the paper that there was any mention made of crushers to crush the coal for the stokers, nor any charge for ash handling machinery. It seems to me that both are items which should have been included in a statement of a plant using coal for fuel with a stoker.

Mr. R. W. Stovel: Referring to Mr. Chester's question, it is probable that the development of the LeBlanc condenser caused the other manufacturers to reconsider their designs and improve their arrangements for mixing, also using better and larger air pumps, resulting in the condition that there are today several makes of mixing condensers on the market which I think equally good, and whether the condenser is a centrifugal type placed below the turbine or whether a barometric type, the

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vacuum at the condenser itself is the same. But with 28 to 29 inches of vacuum unless we use exceptionally large pipes from the turbine to the barometric head and thus spend a great deal of money for these pipes we will have a loss of from ¼ in. to ½ in. of vacuum in this pipe connection.

Furthermore, with the barometric condenser and to protect the engine or turbine we have to use an entrainer at the base of the exhaust riser to the condenser, which entrainer simply fills up with water and decreases the area through which the steam goes thus increasing the steam velocity until further water is carried up; this imposes a further loss of from ¼ in. to ½ in. in vacuum.† So that with the barometric condenser we generally have about a half inch less vacuum at the turbine itself than with the centrifugal type which we hang directly beneath the turbine exhaust outlets.

The reference to the use of superheat in the paper related only to the use of superheat in present day turbine practice as compared with the former reciprocating type units. We did not mean you to infer that superheat was not desirable with engines of all types properly designed for its use.

In regard to the cost of piping in Table 2, which Mr. Chester has compared to the cost of boilers and questioned: The cost of piping includes the piping for the entire station excepting only the condenser water pipe. It includes all the turbine and condenser steam and exhaust piping and excepts only the condenser water pipe.

In regard to the remark that the fine coal shown in the bin on one of the slides looked like slack and hence would not contain 14 000 B.t.u. This coal was Pennsylvania coal, purchased as "run-of-mine" and crushed at the plant, and in no case that I know of, over a period of several years did it analyze less than 14 000. It was more nearly 14 250 as an average.

In regard to Mr. Lincoln's question as to the affect of variations in load on plant design, there is not a great deal that you can do. Your plant has to be big enough to handle the maximum load when called upon to do so. That maximum and that only

†Prof. Trinks states that the entrainer action can be entirely avoided by connecting a vacuum-trap to the lowest point of the exhaust-steam pipe.

determines the total capacity that you have to put in your plant. In general, if you have a known maximum load, you put in enough units so that with one unit held as a reserve, the other units working at their maximum safe capacity will carry this maximum load. Then having determined your total capacity, you install it in that number and size of units which will best meet your varying load conditions, that is you endeavor to select your units so that one or more will be economically loaded at all conditions of the load.

Answering Mr. Lincoln's remark in regard to the Utah plant containing only one unit whereas it would seem that several units might be desirable for economy in load, it must be remembered that this is a standby plant in which the main object was to minimize first cost. The fixed charge of this first cost is the main item of expense in carrying the plant. It may operate five days or five weeks a year and the actual fuel economy in such an operating schedule is negligible. Had the same total capacity been installed in several units not only would the first cost have been increased but the time necessary to get this total capacity on the system in an emergency would also have been increased.

Mr. Darlington's question in regard to the change in plant design if fuel oil is used instead of coal lies outside of the range of the paper. We did not attempt to discuss either producer plants versus steam plants or oil burning plants versus coal plants. Each of these kind of plants are economical and desirable under certain conditions. We assume as the subject of discussion steam plants using bituminous coal for fuel.

As a matter of interest, in California, where they use oil for fuel the practice generally is to arrange the building and apparatus so that stokers and coal handling apparatus can be installed later if desired. The boilers, superheaters and piping, etc., are identically the same as for coal, excepting only the oil burners, piping and storage.

At the American Society of Mechanical Engineers' meeting this month in New York there was presented a very interesting paper giving the cost of a gas engine plant in Allegheny using natural gas, not producer gas. This gave the cost of the plant

exclusive of any producer plant equivalent, as $80 per kilowatt. The paper goes on to say that a steam plant of the same capacity would cost from $100 to $130 per kw., which as we have shown we believe to be twice what a steam plant should cost. If you will add to that $80 per kw. for the gas plant the cost of a producer plant and the building and the foundations required for it you will get a fair idea of the cost of a producer plant as compared with a steam plant, these costs being about as 2:1. Of course, if natural gas is available the comparative costs between gas engines and turbines is quite different.

In regard to the remark that the very pertinent matter of feed water was omitted in the paper it may be said that this was referred to but was contained in that part of the paper Mr. Lyford did not read.

The ash handling costs were not shown in the boiler room group costs because we normally group these with the "Service Equipment" costs. They were included in the larger table No. 1, but not in Table No. 2. The omission of mentioning a coal crusher was simply an oversight. With any plant that is so far from the mines that a continuous supply of slack coal cannot be relied upon it is of course necessary to have a crusher.

Mr. O. S. Lyford, Jr.: The only thing my associate has not answered is Prof. Trinks' question about geographical location as affected by the condition of coal. The point we wished to make in the paper is, that having determined the right coal to use, the design of the station should be the same irrespective of the cost of the coal, but we did not mean that geographical location would not have anything to do with the selection of the coal you should use, or that the character of the coal might not affect the design of the station. For instance as was stated in the paper, if Pittsburgh coal were the right kind of coal to use, you should not design your station any differently because that coal was to be used in New York City, than if it were to be used here in Pittsburgh.

Mr. E. D. Dreyfus:* In view of the comprehensive nature of the subject undertaken by the authors, they deserve much

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credit for having focused the attention of engineers upon important considerations and elements of cost in power station design and operation, and to those variations which may and do ordinarily exist.

One point occurs to me in connection with Table No. 1 which I believe should be mentioned. As has been noted the figures are based upon the maximum continuous capacity of the generating equipment. In my opinion this fact is to be especially emphasized, as many of us are still accustomed generally to thinking of the normal ratings for the main units which provides for a safe continuous overload capacity of 25 percent. The difference in cost in the two cases will be represented by this same percentage, particularly in the turbine generator set and possibly the remaining equipment according to how it happens to be proportioned.

Only with the exception of the auxiliary or stand-by station would reserve capacity usually be omitted, and it would be interesting if the authors would express themselves on this point. In minor operations ,of course, the importance of continuity of service is not very great, but in public utility service it assumes vital significance. The authors might give us their views of what should be customarily allowed in some of the different classes of service. For a comparison with the internal combustion engine, which was brought up in the discussion, the maximum rating is quite logical as gas or oil engines are as a rule, rated very close to their maximum power, i. e., within about 10 percent which may or may not be exceeded according to the variable qualities of the gas sometimes encountered.

Engineers are always bound to differ somewhat in opinion, and consequently I therefore do not hold the same views as the authors regarding recent advance in turbine speed ratings, for instance the employment of a rotating speed of 3600 r.p.m for units extending up to and including 2000 kw. More homogenity obtains in the smaller mass used in the higher speed turbine (peripheral speeds about the same in both cases) so that it may be properly said nothing has been sacrificed in adopting the higher speed. In fact considerable improvement in design has thus been achieved and their operating records have been

observed to be notably better. Turbines are now being built to deliver 4000 kw. at this speed of 3600 r.p.m.

For the range of stations selected the authors, in my mind, have been entirely justified in disregarding the gas engine plant for conditions such as we have in the east. As pointed out unless the price of coal exceeds $3.50 per short ton and the load factor 60 percent, gas plants hardly pay at prevailing cost of installation.

The discussion has elicted the question of barometric vs. low level jet condenser. Although the barometric requires less power, this advantage is in most cases counterbalanced due to the better vacuum produced at the turbine exhaust by the low level jet, effecting a corresponding decrease in steam consumption. Moreover, the draft on the coal pile is not necessarily increased on account of the greater power consumption, for by using steam driven pumps, the exhaust may be returned to the feed water heater, and thus utilized with a higher degree of efficiency. In view of this, the fact that the low level jet may take more power ceases to be an important consideration. Its obvious advantages may be summarized as follows:

(a) Equal or possibly less power required to produce a given vacuum at the turbine exhaust where the discharge and intake levels coincide.

(b) Extremely compact; requires no structural steel supports or bracing.

(c) Short connection to turbine, eliminating loss in vacuum due to steam friction and air leakage from defective joints and porosity* of the pipe, the danger of leakage being increased by exposure of the barometric type to extreme heat and cold.

(d) Liability of diminished vacuum by throttling, (due to water collecting in horizontal lengths of piping and entarainers) removed.

*In cast iron pipe only. Riveted pipe must have perfect seams. No definite tests are on record showing the effect of the prosity of cast iron pipe, but extended experience has shown that if precaution is taken to coat the pipe with good protective paint, a higher vacuum may be obtained, all other conditions remaining the same. Consequently, if the coat of paint does not last any length of time, the vacuum in long exhaust connections will suffer.

Therefore the low level jet appears to be the more favorable excepting however, where the cooling-water supply may be under considerable natural pressure head, or for reasons of water level conditions peculiar to the local system.

Bearing upon Prof. Trinks remarks that he observed in a report test of a Leblanc air pump, that the efficiency referred to isothermal compression was only 14 percent. I do not believe I fully appreciate the value of judging the performance of the air pump on this basis. It is true that his is the scientific method, but for clearness the operating engineer, ordinarily will prefer to regard it a little differently. While, in fact, the vacuum air pump is a compressor, its primary function of course is to evacuate highly attentuated air (such as turbine operation demands). The power consumption per unit volume of displacement at these very low pressure will be less than that of the reciprocating engine pump, but for moderate vacuum around 25 in. the case will be reversed. A definite comparison of this nature for a wide range in conditions will very shortly be offered to one of the engineering societies. Prof. Trinks would exclude the turbine where a heating demand exists. The turbine has already shown itself capable of wonderful development and the latest innovation has been in the form of the automatic bleeder design. As witnessed before in the case of straight power generation, the turbine will also make the engine look to its laurels in this, the steam heating industry, as it possesses greater condensing economy in the non-heating months. Again turbines are rapidly working in the slow speed field, having been aided by the practical development of a large flexible reduction gear, and we therefore find it coupled by this means to efficient D. C. generators, centrifugal pumps, ship propellors and even invading rolling mill work.

Mr. R. W. Stovel: Referring to Mr. Dreyfus' comments on the unit costs as shown in the tables being based on the maximum continuous capacity of the generators, I would say we have done this for three reasons: First, because many turbine units are now sold on that basis; secondly, because such unit costs are more directly comparable with unit costs on water

wheel and gas engine installations; and thirdly, because such generator ratings are a direct measure of their capacity to carry maximum or peak load conditions.

It does not seem to us that the basis for expressing unit costs has any connection with the reliability of the station for continuity of service. To insure reliability, we always consider that in any turbine station one unit, and that the largest one installed, must be considered as a reserve unit, so that with any one unit out of commission, there will be enough generating capacity to meet the maximum requirement. This is surely a much more definite and dependable way of insuring reliability than to consider that the overload capabilities of the running turbines will replace a unit out of commission.

President Walther Riddle: I think the ground has been pretty well covered, and if there is no further discussion, and with thanks of our Society to Mr. Lyford, we will stand adjourned.

[A partial bibliography of the subject of Steam Power Plants is appended and it is desired to acknowledge the assistance of the Technology department of the Carnegie Library of Pittsburgh in its preparation. Editor.]

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REGENERATIVE STOVES: THEIR RELATION TO BLAST FURNACE PRACTICE

By A. N. Diehl*

One of the most important epochs in the history of the blast furnace, and in the manufacture of pig iron, was the introduction of the so-called hot blast or regenerative stove. The principle was first applied by Neilson in 1828, for the purpose of pre-heating the air before its introduction through the blast main into the hearth. The first application was by means of iron pipes through which the blast was forced from the blowing engines, and heat applied outside, thus acquiring the name of the iron pipe stove. It was evident that only comparatively low temperature could be obtained in this manner, 900 deg. being about the limit. The pipes deteriorated very rapidly, which caused a considerable up-keep expense. All the smelting of ore prior to the adoption of the regenerative system, was carried out by means of cold blast, and in some cases, this method is still used.

The application of heated blast was directly responsible for a decrease in fuel consumption per ton iron to about one-half that of the cold blast. It is clearly evident that the simple application of the additional heat units would not be responsible for this enormous lowering of fuel, so we must therefore, look to the increased affinity of the incandescent coke for the oxygen of the air, caused by the higher blast temperature.

The temperature of the products of combustion is raised; also a greater heat margin is established between the temperature of the resultant gases, and the required fusion and superheated temperature of the iron and slag. In other words, we

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could apply a lean gas mixture to a metal, like iron, having a high melting point, without fusing it, consuming in the meantime, an enormous quantity of heat units, if the resultant combustion temperature of the gas were below the melting temperature of the metal. On the other hand, an electric arc, oxyhydrogen or acetylene mixture, would quickly melt the metal with the minimum consumption of heat. This point is demonstrated clearly by the great fuel decrease shown by hot blast over cold blast, and more modernly—by the Gayley Dry Air Process. Both of the latter named applications aim to accomplish the same purpose, namely: the raising of the hearth temperature, while the fuel results cannot be accounted for in a straight thermal calculation. The application of excess oxygen to the air, or electric energy, will carry this idea further. The cost of these equipments might exceed the saving affected, and in this manner, might be prohibitive. On account of this increased hearth efficiency, more ore can be used per charge, the proportion of ore to coke can be raised to a point establishing the furnace equilibrium necessary to produce the required quality.

The nearest approach to a constant in blast furnace practice, is the combustion of carbon. In normal practice, with the losses and leakage considered, about 60 cu. ft. of air are required for each pound of coke burned. By using this factor, the daily consumption of coke can be approximated, and by having a known ore burden ratio, with its determined pig iron content, the tonnage may be closely predicted. If the volume of blast is constant, the problem of fuel consumption determines a great number of the remaining points in blast furnace practice. If the burden ratio is low and ore is lean, the tonnage will be low, while if the conditions will allow the tonnage will be increased by raising this ratio, which in turn will effect the entire practice.

It is generally considered that the use of 100 deg. additional heat in the blast, will decrease the coke per ton of iron from 50 to 60 lb. This is apparently borne out in a number of cases, but above 1300 to 1400 deg., the saving becomes less, as we then approach the point where the gas becomes less reducing. It

was formerly considered that a ratio of two to one between carbon monoxide and carbon dioxide was the lowest limit of reduction. This has been shown to be in error, as frequently in low coke furnaces we have 15 percent carbon dioxide to 20 percent carbon monoxide, with an extremely good grade of iron and good furnace practice. The primary object of blast furnace management is the production of a commercial pig iron; the secondary, to produce it as cheaply as possible; the tertiary, to produce as large a tonnage as will be justified by the first two conditions.

About the year 1860, fire brick stoves replaced the former pipe construction. Passing through various stages of development, we arrived at our present stoves, 22 or 23 ft. in diameter, and 100 to 110 ft. in height, having 60 000, or more, square feet of heating surface, and built to withstand blast pressures which very often reach 30 lb. One of the quickest ways to obtain the proper quality of pig iron is by regulation of blast temperature.

It has been the practice in Germany, as well as in the United States, to use as high temperature as can be consistently applied; a number of plants stating that they use all the heat all the time. While this may be true, yet in ordinary blast furnace practice, the quality of iron is a factor, and the blast temperature must be so regulated as to obtain the grade of iron desired. An ideal condition, in regard to analyses of raw materials, uniform atmosphere, and no irregularities consequent to operation, would be receptive to an extremely high blast temperature. Unfortunately we can only approach these conditions, and must therefore resort to a regulation of heat in many cases where the furnace becomes too hot, or on the other hand becomes chilled. In order to make this heat adjustment we have two methods: One is—running two stoves on blast, one called a hot stove and the other a cold stove, and regulating the air passing through these stoves so as to maintain a constant temperature. The other is, by means of a cold wind or mixer valve, whereby the air is by-passed to the hot blast main. A regulation of this mixer valve will give the desired uniformity

if it is carefully attended to. A number of automatic mixing arrangements have been installed, but none have been noticeably perfected.

One of the best arrangements proposed for uniform air is the construction of an equalizing stove filled with checker work placed between the hot blast stoves and the furnace, and through which all the blast is allowed to pass. This checker work will absorb the peak temperatures, and after the stove runs down, will in turn give up its own heat, thereby reducing the range of temperature between the stoves to a very marked degree. It has been almost the universal practice to carry three stoves on gas, and one on blast; the stoves dropping from 75 to 125 deg. an hour if in good condition. This drop is dependent entirely on the quantity of heating surface and volume of brick work contained in it, as well as to the condition and construction of the stove. If the stove is dirty or the brick vitrified, its capacity for absorbing and giving out heat, is gradually reduced, and the stove will run down very quickly. In order to obtain these high heats, we have developed from the pipe stove to one of high grade fire brick. The problems which confront us in the construction are numerous.

There are two principal classes of stoves, namely center combustion and side combustion chamber. Center combustion are principally of two types—two-pass center combustion stoves, as of the Kennedy & McKee type, and three-pass center combustion, Massicks & Crookes, or the McClure. The side combustion stoves may also be divided into two types, namely, two-pass side combustion and four-pass side combustion stoves. In all types the gas is allowed to enter the combustion chamber through a gas burner where it is consumed, and the products of combustion passed through the various passages through the checker to the stack. The air for combustion is sometimes mixed in a properly constructed burner, or allowed to pass through air doors, so as to mix with the gas and be consumed at as low a point in the combustion chamber as possible. It is evident that the brick work must be of the best obtainable quality to withstand these high temperatures, and capable of carrying the

heavy weight of masonry superimposed. The top of the checker work should also consist of high grade brick, while second quality can be used for the bottoms and final passes.

The combustion chamber is common to all types and is built up of first grade brick. There is sometimes a false wall run about half the height of the stove inside the combustion chamber. This false wall is not tied, but so arranged that it can be easily removed in case of its becoming badly burned. The top courses of the second pass also are constructed of first quality fire brick, which extends down about twenty to thirty feet; second quality brick being used from there to the bottom of the second pass, and also in the remainder of the stove. The bottom brick should be sufficiently strong to be able to take care, not only of the expansion and contraction which is going on continuously while the stove is in service, but also to be able to carry the masonry above. Proper channels or flues should be constructed at the bottom of the stove to pull equally on all checkers, thereby maintaining a uniform and equal draft throughout the entire stove area. The equalization of draft is one of the principal factors entering into successful operation, and attention should be strongly given to this point.

The location of the stack on the center combustion three-pass stove, is directly on top of the dome, and in this manner serves to pull equally over the entire stove area. This gives an equal pull on all checkers. On the other hand, the stacks are independent, and require some little time for heating after the stove is taken off blast. The draft conditions are better when the stack becomes thoroughly heated. This same objection can be raised to all stoves having independent stacks. The question of uniform draft is a harder problem in a two-pass stove. In the center combustion this can be accomplished by means of a flue, constructed directly beneath the combustion chamber in the center of the stove with small converging flues leading to it from the checker work, and this leading in turn directly to the stack. This will collect the draft in the center of the stove, making an equal pull on the checkers. In the side combustion this equal draft is attained, in many cases, by a double flue leading to the stack and is known as the Morrison-

Kennedy construction. Two adjustable draft tubes are used. When the stoves are put on blast, these are drawn back and the doors bolted in position making a positive seal and allowing no air leakage. I would favor a single stack of sufficeint dimensions for one or two sets of stoves, rather than independent stacks. This single stack will not be affected by cooling when a stove is put on blast, as there will always be a number of stoves drafting through it.

At the Duquesne Blast Furnace of the Carnegie Steel Company, we have at present, three different types of stoves: The center combustion, two-pass; side combustion, two-pass, and three-pass stoves. The construction of the two-pass side combustion, is possibly the simplest—a strong point in its favor. A number of these stoves have been in use for many years and have given good satisfaction. One of the earlier objections was the proper construction of the combustion chamber, considerable trouble being experienced by the giving way of the walls, due to unequal expansion. Most of these difficulties have been over-come in the present construction. This stove is built up of standard size brick, so laid as to break all possible joints. We have also endeavored to cut out shapes wherever possible. The stove operates on dirty gas and has given us very good results. Our two-pass, center combustion stoves are of the Kennedy type. The original stoves were constructed of concentric key boxes. We have since rebuilt some of these stoves with the standard size brick. They have individual stacks and the draft is unequally distributed; the checker work nearest the stack does most of the work until that portion becomes clogged with the dirt. This lowers the efficiency of the stove to a considerable extent. The three-pass stoves are capable of giving the highest heat, but are of a more complicated construction. A dome separates the second and third passes on top of the stove, and must be so constructed as to allow for expansion and contraction, which very often lead to cracks requiring attention. The blast is admitted at the top of the stoves through a mushroom valve, brought down over the dome through the third pass and through the second pass up under the dome again, where it is deflected through the combustion chamber. In case of

cracks or leakage in the second or third passes, both the blast and air are by-passed, and go directly through the stoves without following their proper passages. This leads to great inefficiencies. We have experienced these difficulties in several instances.

A blast furnace will produce about 150 000 to 160 000 cu. ft. of gas per ton of iron, 10 percent of which may be assumed as loss. One-third of the remainder will be burned in the stoves for the pre-heating of the blast, while the remaining two-thirds can be divided for power purposes and used at the boilers or for driving internal combustion engines. The gas, as it leaves the furnace contains a considerable quantity of dust, some of which is deposited in the dust catcher and mains, the finer portions being carried on to the point of gas consumption. This fine dust is carried into the stove with the gas, some of it impinging on the walls of the combustion chamber, clinkering, and forming heavy masses of cinder. Quite a lot of the dust passes through the combustion chamber and lodges in the checkers, and in the bottom of the stoves. Cleaning doors are provided for the removal of such dirt when its removal is possible without taking off the stove. The dirt in the bottom of the second pass is very seldom fused, and can be scraped out readily, while that which remains in the checkers must be removed by means of iron weights or dollies.

If a stove is kept on too long, the checkers may become almost entirely closed up, and the stove will neither absorb heat nor give it up. A glazing effect often takes place, which will also prevent the absorption of heat, and will lower the efficiency of the stoves. It is, therefore, desirable to keep the stoves as clean as possible. With the dirty gas we are forced to remove the dirt from the cleaning doors once a day, and take the stove off for complete cleaning about once every two months, which process requires about five or six days. The stoves have a checker area equal to nine inches square which are frequently clogged to about three to four inches square, while some of them are closed completely. This is especially noticeable on stoves having a separate stack, the checkers on the side toward the stack closing first. It is thus very evident that for one-third of

the time, the furnace is deprived of one-fourth of its heating surface capacity; the remaining three stoves, during such periods of cleaning, run down very rapidly. For this reason, in a number of recent constructions, five stoves have been advocated, so that when one is taken off for cleaning, the loss of heating surface is not so essential and the furnace is less affected. The alternative is the erection of four large stoves with the greater heating surface and smaller checker opening, say six inches square and using washed gas.

We have been using washed gas on four sets of stoves for about three years and at no time have we removed any stoves for cleaning. During times of suspension of operation for various reasons, we have gone into the stoves and do not find more than a coating of dirt on the top of the checkers, and in the checker walls. After a year and a half of service, one set of stoves was taken off and not more than 10 000 to 15 000 lb. of dirt removed from the entire set. The brick work in the combustion chamber, at the point of the flame impingment, showed a fused surface about an inch in thickness. At the bottom of the second pass was found an impalpable deposit of a pinkish color of the following analysis::

Silica	22.80	
Iron	6.00	$=Fe_2O_3$—8.57%
Manganese	1.50	$=Mn_3O_4$—2.09%
Alumina	15.73	
Lime	21.42	
Magnesia	2.50	
	20.90	Potassium Oxide
	6.08	Ignition Loss

The gas is washed through spraying tower washers, where it is at present cooled from 350 deg. to five or six degrees above the temperature of the washing water, and the dust removed to an average of about 0.2 of a grain per cu. ft. The year 1910 showed ingoing water to have an average temperature of 55 deg. and the temperature of the outgoing gas, 72.3 deg., or a difference of 17.3 deg. We have since re-designed the scrubbers, and now show only a difference of five degrees between the water and out-going gas. The results are obtained with the same water consumption per minute and a greater gas volume.

The moisture, which will average 30 to 35 grains per cu. ft. in the raw gas, is removed down to a point about one-half a grain above the saturation point, at the temperature of the gas as it leaves the scrubber, four to five degrees above the temperature of the cooling water.

About 30 000 cu. ft. of gas are passed through each twelve foot scrubber per minute, where it is repeatedly sprayed by means of a cut off valve having a revolving core, the water spraying through nozzles and is broken up so as to bring it into very intimate contact with the gas. That this contact is attained, is evident by the close temperature of the gas to the entering cooling water. There are 815 gallons of water per minute used in each tower. The average since January 1st, is 35 cu. ft. gas per gallon of water. There is some dirt deposited in the clean gas main, especially at such paints where the main makes a bend, and these points must be cleaned out from time to time. If the gas is insufficiently cooled, it will pick up moisture to such an extent as to make it incombustable. In some cases, on a number of stove tests which we have run, the efficiency of the clean gas stoves is about eight percent higher than that of the dirty gas.

The tables attached will show some of these comparisons. A comparison of stove equipments, in the different plants shows a decided lack of uniformity in regard to heating surface required for different size furnaces. As an illustration, there are two modern plants, each having furnace bosh diameter of 22 ft. with 134 000 and 223 000 sq. ft. of heating surface respectively. Both furnaces should be capable of the same tonnage production. I should strongly advocate the latter figure as the better proposition, for with this heating surface, 1100 or 1200 deg. could be carried with little difficulty when furnace conditions would permit. Fire brick is a poor conductor of heat, and therefore, the exposed area, or heating surface, should be as large as possible. The volume of brick work must be strong enough, however, to withstand all the strains to which it will be subjected. It is evident that with a consumption of 5000 cu. ft. of gas per min. that a too small heating surface area would allow extremely high stack temperatures. This would introduce a loss which

TABLE No. 1
EXCERPT FROM STOVE TESTS

Stove.	Heating surface sq. ft.	Volume of brickwork cu. ft	Fuel gas.	Volume fuel gas per [illegible]	Calorific value of fuel gas B.T.U.	Blast per Min. cu ft	Temperature flue gas Max	Temperature flue gas Min	Temperature flue gas Avg	T[illegible] Max	T[illegible]	T[illegible]	Heat data Absorbed blast Percent	Heat data Absorbed 1 [illegible] flue gas Percent	Stove on gas [illegible]	[illegible]	[illegible]	[illegible]
1 Center Comb. 3-Pass	49865	20831	Clean	4282	108.5	36328	680	370	630	1555	1270	143	63.37	17.53	172	[illegible]	[illegible]	[illegible]
2				4627	105.8	35742	720	565	670	1609	1360	146	62.24	17.40	179	[illegible]	[illegible]	[illegible]
3				3847	104.0	36512	650	540	619	1440	1235	[illegible]	61.69	17.55	180	[illegible]	[illegible]	[illegible]
4				3356	104.4	36109	640	540	614	1335	1135	1231	66.02	16.87	181	[illegible]	[illegible]	[illegible]
Average.				4010	104.1	36170	685	554	633	1487	1250	[illegible]	63.30	17.34	178	[illegible]	[illegible]	[illegible]
1 Center Comb. 2-Pass	39220	17974	Clean	3535	104.3	40030	475	370	412	1310	800	[illegible]	61.76	21.64	175	[illegible]	[illegible]	[illegible]
2				3523	94.1	32905	670	495	525	1440	1030	1200	53.26	25.70	171	[illegible]	[illegible]	[illegible]
3				3497	102.1	37575	700	490	615	1200	850	1051	44.03	31.17	179	[illegible]	[illegible]	[illegible]
4				3648	104.5	35590	650	500	624	1740	1035	1156	61.24	20.14	172	61	[illegible]	[illegible]
5				3459	94.3	40580	525	420	441	1451	1026	1201	64.45	19.28	179	84	[illegible]	[illegible]
6				2595	99.7	34343	680	485	612	1310	970	1076	66.73	13.16	181	60	[illegible]	[illegible]
7				3156	96.0	39632	635	430	489	1340	1010	1162	65.26	12.33	190	57	[illegible]	[illegible]
8				3092	99.2	35852	525	420	476	1470	1030	1149	61.98		182	57	[illegible]	[illegible]
Average.				3368	98.3	37951	595	451	540	1388	989	1094	58.60	20.40	184	57	.6	1.[illegible]
1 Center Comb. 2-Pass	39220	17974	Dirty	1150	103.2	39149	860	610	785	1450	1015	1163	47.13	29.80	200	66	[illegible]	[illegible]
2				4737	94.9	39000	915	650	819	1460	1000	1201	51.20	24.95	190	56	[illegible]	[illegible]
3				4241	105.0	38735	960	620	864	1410	990	1179	50.68	24.29	199	51	[illegible]	[illegible]
4				3888	99.4	38780	930	600	813	1425	1000	1115	56.57	24.95	119	57	[illegible]	[illegible]
Average				4248	100.6	38916	916	620	821	1336	1001	1176	54.24	25.85	177	59	[illegible]	[illegible]
1 Side Comb 2-Pass	30725	7194	Dirty	2832	79.6	35802	510	340	457			1047	42.30		179	76	[illegible]	1.17
2				3114	84.1	36802	550	295	175			985	50.3		174	54	[illegible]	1.56
3				3061	82.6	36022	430	320	377			944	57.90		167	45		
4		21854	5330	2445	83.1	35892	730	305	567			974	61.90		196	49	0.26	2.24
5				2772	75.8	35802	540	390	478			991	62.20		173	51		
6		33632	8204	3571	83.2	36400	605	495	600			956	56.10		180	54		3.58
7				3857	87.9	36400	690	450	606			990	68.20		166	60	0.17	1.77
Average.				3091	82.7	35990	583	370	509			977	67.30		176	49	0.21	1.99

Note: Side Combustion Stove as above, volume of brickwork is for checkers only.
Center Combustion Stoves, Duquesne.
Side Combustion Stoves, Foreign.

sible. The volume of brick work must be strong enough, however, to withstand all the strains to which it will be subjected. It is evident that with a consumption of 5000 cu. ft. of gas per min. that a too small heating surface area would allow extremely high stack temperatures. This would introduce a loss which

TABLE NO. 2.

SHOWING HEAT LOSSES IN STOVE PRACTICE DUE TO INEFFICIENT COMBUSTION OF [illegible]S

Test No.	Volume of flue gas per Min. cu. ft.	Volumetric ratio of flue gas to fuel gas 2	Volume of flue gas per Min. cu. ft. 3	Calorific value of flue gas B. T. U. 4	Average temp. flue gas 5	Flue gas. Percent CO 6	Flue gas. Percent O_2 7	Heat losses in flue gas due to CO 8	Heat losses in flue gas due to O_2 9	Volume of dry flue gas per Min. cu. ft. 10	Volume of air per Min. cu. ft. 11*	Total heat losses due to inefficient air. Percent 12	Coke equ. of heat losses per Hour Lb. 13	Coke equ. of heat losses per day per Ton 14†
1	4282	1.993	8534	108.5	690	0.47	2.29	2.46	2.15	30.11	482.71	4.61	105.3	7582
2	4527	1.718	7777	106.3	670	0.12	1.18	0.53	1.07	9.33	116.11	1.60	37.7	2714
3	3847	1.540	5924	99.0	629	2.10		11.61		142.18		11.61	217.5	15660
4	3336	1.849	6260	104.4	611	0.11	2.94	0.50	2.70	8.30	349.61	3.29	35.5	3996
Average	4010	1.775	7049	104.4	633	0.77	1.65	3.77	1.97	17.12	208.57	5.24	104.0	7763
1	3838	2.928	11238	104.3	442	0.60	8.00	4.70	8.31	67.43	4116.25	13.01	256.1	18439
2	3623	2.000	7363	94.1	625	0.60	6.50	5.15	7.53	44.18	2182.00	12.63	207.3	14925
3	3497	2.574	9001	102.1	615	0.80	9.70	8.31	12.72	72.00	3098.00	21.03	369.1	26576
4	3548	2.078	7373	104.5	624	0.80	4.60	6.37	4.64	66.36	1461.75	9.41	221.7	15962
5	3489	1.757	6130	94.3	612	0.80	2.90	1.52	2.60	36.78	701.72	5.12	115.2	8294
6	2806	1.805	5063	99.7	441	1.10	2.50	6.22	1.24	55.69	651.92	7.36	110.2	7934
7	3156	1.281	4043	96.6	482	2.00		9.30		50.86		9.30	140.8	10137
8	3092	1.568	4817	99.2	476	3.30		14.34		158.96		14.34	216.6	16595
Average	3368	2.134	6853	99.3	540	1.26	4.27	7.12	4.62	71.53	1676.51	11.87	204.6	14733
1	4120	2.415	9950	103.2	788	0.80	5.60	6.32	8.48	79.60	2473.38	13.80	288.5	20772
2	4736	1.884	8731	94.9	819	0.80	0.60	4.11	0.78	69.85	37.74	4.89	97.0	6984
3	4241	1.731	7341	105.0	864	0.80	1.00	3.75	0.80	68.73	210.62	4.55	100.0	7200
4	3898	1.654	6447	99.4	817	0.60		2.85		32.68		2.85	54.2	3902
Average	4248	1.911	7867	100.6	821	0.75	1.80	4.01	2.39	60.21	641.38	6.40	134.9	9712
1	2832	1.834	5194	79.6	455	0.82	4.17	6.23	4.73	42.59	1885.46	9.94	119.4	7935
2	3114	1.546	4811	84.1	475	0.24	1.56	1.45	1.09	11.66	290.72	2.64	32.8	2362
3	3061			85.6	377									
4	2448	1.718	4205	83.1	569	0.26	2.54	2.08	2.92	10.93	484.42	5.00	42.6	3067
5	2772			76.8	478									
6	3524	1.778	6266	83.2	660		3.58		3.16		1071.12	3.16	68.0	4176
7	3887	1.574	6118	87.9	606	0.17	1.77	1.01	1.60	10.10	491.28	2.61	43.7	3146
Average	3091	1.690	5319	82.7	599	0.21	1.99	2.15	2.49	16.07	757.44	4.66	57.5	4137

*Col. No. 11—Over and above that required to oxidize the CO present in the flue gas.

†Col. No. 13—Per stove per hour and based on coke having a calorific value of 12 200 B. T. U. per lb as received.

‡Col. No. 14—Based on four stoves per furnace, or 72 stove hours per day on gas and 24 stove hours per day on blast

Note: All gas volumes and calorific values are at Standard Conditions, 62 F. and 30 in. Hg

Above test Numbers correspond to those given in Table No. 1.

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EXAMPLE OF STOVE TEST FORM

	Data.		Three-pass central combustion chamber. Clean gas	Two-pass central combustion chamber. Clean gas.	Two-pass central combustion chamber. Dirty gas
1	Date of test	1909	6/11	8/19	9/27
2	Furnace and stove number.		No. 5 Fc. No. 1	No 4 Fc. No.1	No. 2 Fc No. 3
3	Size of stove		22' by 100'	21' by 96'	21' by 96'
4	Area of combustion chamber	sq ft	25.78	28.47	28 27
5	Area of flues, 1st. pass	"	78.25	.....	
6	Area of flues, 2nd. pass	"	36.52		
7	Area of checkers	"	...	77.91	77 91
8	Total heating surface	"	49,865	39,220	39,220
9	Cubic contents	cu ft.	20,831	17,974	17,974
10	Equivalent of 9 in. brick		360,000	135,560	135,560
11	Ratio Heat. Sur. to Cub. Contents		2.39	2 18	2 18
	PRESSURES.				
12	Gas in main	in. Water	1.50	1.50	8.00
13	Gas in burner	"	0.82	0.54	3.77
14	Pitot tube	"	0.122	0.055	0.1085
15	Draft at chimney valve	"	0.41	0 50	1.66
16	Blast pressure	lb	16.1	15.4	16.96
17	Barometer	in. Hg.	29 32	29.17	29 36
	TEMPERATURES.				
18	Furnace gas at burners	F.	86.6	88.9	300.2
19	Atmosphere	"	72.5	74.0	96.6
20	Cold blast	"	152.8	191.7	227.0
21	Hot Blast—Maximum	"	1600	1310	1425
22	Hot Blast—Minimum	"	1360	970	1000
23	Hot Blast—Average	"	1462	1076	1148
24	Chimney—Maximum	"	720	680	930
25	Chimney—Minimum	"	565	485	600
26	Chimney—Average	"	670	612	813
27	Engine room, dry bulb	"	89.5	96.0	102.0
28	Engine room, wet bulb	"	72.5	79.0	87.0
	DURATION				
29	Stoves on gas	Mins.	179.0	198.75	148.75
30	Stoves on blast	"	60.0	64.0	50.5
	GAS.				
31	Heat per Cu. Ft. at 62 F.	B. T. U	105.8	94.3	99.4
32	Total gas at Temp. & Pres. at Burner	cu. ft.	867,076	693,439	821,669
33	Total gas at 62 F. and 30 in. Hg.	"	810,333	631,693	579,827
34	Gas per Min. at Temp. & Press. Burner	"	4,844	3,659	5,756
35	Gas per Min. at 62 F. and 30 in. Hg.	"	4,527	3,489	3,898
36	Analysis of gas by Vol. Carbon Dioxide	percent	15.90	13.06	12.40
	Carbon Monoxide	"	25.00	25.78	25.40
	Methane	"	1.20	0.00	0.00
	Hydrogen	"	4 20	3.69	5.80
	Nitrogen	"	53.70	57.47	56.40
37	Moisture per Cu. Foot of gas	Grains.	13.53	14.79	20.59
38	Analysis of chimney gas, Carbon Dioxide	percent	24.39	21.30	22.70
	Oxygen	"	1.18	2.90	0.00
	Carbon Monoxide	"	0.12	0.80	0.60
	Nitrogen	"	74.31	75.00	76.70
40	Air excess co-efficient		1.20	1.08	0.993
	BLAST.				
41	Air blown per Min. at Eng. Room Temp.	cu. ft.	38518	44460	42671
42	Grains moisture per cu. ft.		6.42	8.66	8.48
43	Air blown per min. at 62 F.	cu. ft.	35742	40580	38780
44	Total dry air blown	lb.	163836	172959	144993
45	Total moisture blown	"	2121	3170	2613
	HEAT.				
46	Total heat absorbed	B. T. U	52,756,822	37,666,082	32,834,652
47	Total heat absorbed	"	85,733,124	58,404,422	57,364,804
48	Efficiency	percent	62.24	64.48	56.97
	WORKING CONDITIONS.				
49	Time in service since last Cleaned	Mo. Day	2—29	7—19	1—14
50	Burner opening	Ins.	9	full	5
51	Cleaning door	"	0	3	3
52	Blow off valve open	turns	4	0	0
53	Piston displacement	percent	92.80	91.27	90.88
	HEAT BALANCE.				
54	Heat absorbed by blast	percent	62.24	64.48	56.97
55	Heat lost in flue gases	"	17.46	19.28	24.95
56	Heat lost due to incomplete Comb.	"	0.53	4.52	2.85
57	Heat lost hydrogen	"	3.48	3.36	3.36
58	Heat lost by moisture in fuel gas	"	0.45	0.58	1.48
59	Radiation, unaccounted for, etc.	"	15.90	8.78	10.39
60	Efficiency of burner	"	99.47	95.48	97.15
61*	True thermal efficiency	"	62.57	67.53	68.64

*Item No. 61. 54/60

would not be present in case there was sufficient heating surface, yet at times, in order to get a high temperature in the stoves, this quantity of gas may be required.

The performance of any given type may be termed good or bad thermally, according to the extent it absorbs and makes available to the blast, the heat delivered it in the regenerative gases. This may be stated as a percentage of the total heat available to the burner. However, it is manifestly unjust to consider the burner and stove as a unit in this respect, that is to say, the stove proper and the burner should be separately considered. Clearly the stove is susceptible to the total heat made available to it by the burner and its efficiency should be stated in this manner, otherwise it will be more or less misleading. If it is desired to state the efficiency of the whole, this then can be done in a manner similar to that employed in boiler practice—thus it may be stated as the "efficiency of the stove and burner" or the "efficiency of the stove", the latter taking no account of the burner. It is believed that this would be less misleading, and that for comparisons, the statement should be made in this way; thus furnishing an insight into the performance of not only the whole, but also that of the burner and stove proper. Comparisons of component parts are thus possible, aiding in determining which is at fault, the stove or the burner or both, as compared to some standard condition. This brings us to a consideration of the elements entering into and making for efficient operation of stoves, thermally. These may be summarized and collected in consecutive order.

First: Perfect combustion of the fuel gas with but slight excess of air, the result being a higher calorific intensity of the products of combustion making possible a higher temperature of the heat absorbing medium of the stove. Also due to the higher pyrometric effect of the regenerative gases, transfer of heat to the surrounding media will be much more rapid, due to the greater temperature difference. Efficient burning of the fuel gas may be accomplished by proper proportioning of the burner, which should be such that the gas and combustion air shall be thoroughly mixed and the ratio of gas to air such that combustion of all constituent gases will proceed easily. The average blast furnace gas requires about 0.7 of a cubic foot of

free air for perfect combustion. This however does not allow for any variation and in practice should be carried to the proportions of about one to one. The air excess in this case will be slight and the loss in heat would be small, while sufficient oxygen is practically assured to meet all requirements in fluctuatiou of the constituents. It must be borne in mind that if dirty gas is used in the burner in the theoretical proportions, there is great danger of fusing the brick in the combustion chamber at the point of flame impingment, Heavy flue dirt clinker is also liable to form in the combustion well, clogging up the same. This effect is not especially noticeable in the use of clean gas and its combustion can be regulated in a more satisfactory manner.

Second: Draft should be symmetrical and uniform over the full area of the stove and the stack should be so placed and its communication to the stove such, that this will be the effect. The feature of draft has called for considerable comment and opinion seems to differ as to the best location of the stack in relation to the stove. Some are favorable to the individual stack on the ground that the stoves are not subject to the discriminatory features of the single large stack, often claimed for it, which is evidenced in its tendency to favor the closest situated stoves in the matter of draft intensity. On the other hand, opponents of the individual stack claim, that owing to the cooling of the stack during the period the stove is on the furnace, its influence is not properly exerted again until sometime after the process of regeneration has advanced and the stack has had an opportunity to become heated again. Too much importance cannot be attached to the necessity of having the draft symmetrical and uniform. The ill effects of not having it are many and may include such as: Local clogging in the regions where the draft is intensified, high velocity of combustion products with its consequent reduction of time contact and heating surface, intensified local temperatures producing glazing, vitrification and unequal expansion and contraction, highly heated surfaces confined to a comparatively small area and ultimately shifting the seat of operation to another point when resistance in the original path has become too great. These are conditions

encountered in the actual operation of many stoves and thoroughly familiar to those having to do with stove and furnace operation. It might be added in passing that the superimposed stacks, those finding application in stoves of the three-pass type, seem to have eliminated the difficulty of obtaining symmetrical draft, although having the disadvantages attributable to the cooling resulting during the period the stove is on the furnace. The ills above cited are particularly pronounced in the two-pass center combustion chamber, where communication to the stack is so effected as not to be conducive to symmetry in draft.

Third: Stack temperatures are dependent, first, upon the extent of heating surface; second, absorbative power and mass of brickwork; third, time contact, which is determined by the intensity of draft; fourth, the volume of the recuperative gases; and fifth, the blast. The necessary qualifications required of the lining to meet the first of these have been discussed and will not be recalled. In the matter of time contact, however, it is clearly a condition depending upon the volume of the blast to be heated, volume of the gases furnishing the necessary heat and the clearance volume of the stove. The time required for unit volume of either in passing through the stove, has no little influence upon the ultimate temperature at which it leaves, whether it be the blast or the recuperative gases. This necessarily follows, as the element of time is required to effect a complete transfer of heat and any reduction in the time will result in carrying considerable heat to the stack, in the case of the combustion products, conversely in the case of hot blast. This will appear as a sort of reversible cycle, and is accounted for by the fact that we are handling gases in both cases. The time required by a unit volume of regenerative gases in passing through the stove will be considerably more than that required by the blast, the volume ratios of blast to heating gases averaging about four, or five, to one in the most approved practice. The item of stack temperature is one of the most important entering into stove operations and its influence upon the economies to be realized, not only on account of the enormous heat losses represented by abnormally high temperatures, but the deleterious effect upon chimney valves and seats where these are not water

cooled. Heat losses in flue gases have been noted, constituting as high as 35 to 36 percent of the total heat entering the stove in the fuel gas, which added to other losses encountered will often run up to 50 or 55 percent of the total heat made available to the stove.

The tendency to conservation and the rapid increase in the cost of coal, consequently coke, has resulted in accentuating effort in the economical and efficient consumption of blast furnace gas. This is a question of serious importance to furnacemen of today and they have come to appreciate the value of a by-product not long since looked upon as a "necessary evil." Heretofore its consumption proceeded regardless of efficiency and economy. Today this same "necessary evil" should and is receiving the serious consideration of a majority of furnace managers, and all steps are being taken having in view its conservation by economical and efficient consumption. Its value as a fuel, therefore its value as a source of energy, is not only appreciated in its application to the hot blast stove but in other directions such as the steam boiler, internal combustion engine, and many other forms to which it is admirably adapted. Thus the wasteful and inefficient consumption of this valuable commodity, has come to be looked upon in the light of an abuse, consequently furnacemen have turned their attention to hot blast stove construction and the economical importance of its proper design, together with a conscientious regard for the quality of material that shall enter into its construction; all of which have a direct bearing upon the value and efficient consumption of fuel gases. Considerable attention has also been directed to the cleaning of gas as a means of economy in stove practice, a number of plants having extensive washing systems in operation.

Careful study of the appended tables will clearly reveal some advantages in the use of cleaned gas for stove purposes, among which might be mentioned the possibility of higher blast temperatures, lower fuel consumption, uniformly higher thermal efficiencies, to which might also be added the absence of stove cleaning gangs and the interruptions of service consequent upon the use of dirty gas. I attach two tables showing abstracts from some stove tests, also the saving in coke which could be made

if the gas had been burned perfectly. I am also attaching some detailed tests which are quite full and may contain some interesting data. One test was made on a three-pass stove; the other two were made on center combustion two-pass stoves, the gas being dirty in one case and clean in the other. Most of our stove tests are made according to this form, the tests attached being average ones.

All together, there are many other items of interest and importance in connection with stove practice, and it is hoped that this short recount may serve to still further enliven interest and effort in the direction of proper stove design, operation and the economical importance of fuel consumption.

DISCUSSION

Mr. E. L. Messler:* The question of construction of economical regenerative stoves for blast furnaces has not until lately been very carefully studied as otherwise there would not be the wide variation Mr. Diehl speaks of in heating surfaces, etc., at various plants, but it is now being taken up, investigated and studied in a much more logical manner than heretofore.

The points which come up for decision in connection with stove construction are about as follows:

1st. The amount of actual wind to be heated—not the piston displacement but the actual amount which runs from 70 to 90 percent of the piston dsplacement.

2nd. The amount of blast temperature it is desired to carry steadily.

3rd. The temperature of the entering gas, its pressure and calorific value.

4th. The size of the stove shell to be used.

From these four together with the assumption that the average temperature of the outgoing gases shall be 500 deg. which will give good economy in gas, the other points entering into the stove construction are capable of being figured and are:

The required heating surface of the brick in the stove.

The cubic feet of gas which should be burnt to get good gas economies.

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The area of the burner proper.

The amount of air which should be used to produce proper combustion.

The area of the chimney valves.

The height and size of the stack to produce a moderate draught which will not tend to cause channeling by the gases. In this connection it may be a question if some form of induced draught which might be capable of being kept constant or varied as the conditions warranted would not be better for gas economies than the present practice of using stacks.

The type of stove can then be determined almost exclusively on its mechanical construction as if the required number of B.t.u's are put into a stove in the form of gas, the gas properly burnt through the mixture of a correct amount of air and the stack temperature is kept down, the heat units which must go into brick work and then into the air each time the stove is put on blast must be the same no matter what style stove is used assuming that the radiation is equal and that there is a proper distribution of the gases.

This point of radiation, however, is not exactly the same in all types of stoves, but just how much the variation is, I doubt if any one has determined. It is certain, however, that the stove whose hottest part is always in the center with the cooler parts on the outside will theoretically radiate the least heat.

The point made by Mr. Diehl regarding the use of more cubic feet of gas in a stove than the surface of the brick requires or in fact will theoretically take seems to me especially worthy of notice. The loss due to the extreme stack temperature will be very great and this in these days of conservation is extremely bad practice.

Mr. Diehl says the high stack temperatures have a deleterious effect upon the chimney valves but there is also the fact that the changes in temperature in the brick work will be extremely violent and very hard on it. Thus, if the temperature of the waste gas is say 500 deg. when the stove is put on blast, the brick at this point, which is close to where the cold blast enters at about 100 deg., will only be about 350 to 400 deg., or a difference of 250 to 300 deg. from the entering blast; while if the temperature is run up to 1000 deg. the difference will be about 750 to 800

deg. This extreme variation which cannot help but injure the brick in time and cause the failure of the lining at this point, may be one of the principal causes of the trouble with the domes of the three-pass stoves.

It is apparent then as Mr. Diehl has pointed out that the gas burners should be so designed as to get the greatest possible intimate mixture of air in the proper quantity so that the gas may be properly burnt as near the burner and as far away from the chimney valve as possible; that the heating surface of the stove should be ample to take care of all the heat units that will be required of it to heat the air; that the radiation should be kept down; that the connections to the chimney valve be designed so as to give as near uniform distribution as possible and that the draught be such as to handle only the amount of gas required to be burnt, as to use more will not only give any hotter blast but will be inefficient in gas combustion and mean greater repairs to the brick work and valves.

Such a stove, I believe, could be designed combining all of the advantages of the three-pass center combustion stoves with few, if any, of its disadvantages and would give a most efficient one in every respect.

Mr. Diehl's paper also brings out another point very clearly, namely, that if a certain size stove, a chimney valve and a stack which are together giving a certain amount of heat to the blast when pushed to the limit, which would mean high stack temperature, be relined with brick having a greater heating surface by decreasing the size of the checker openings, a greater blast temperature will be available with greater B.t.u economy; no change whatever being made in the burner, chimney valve or stack, as the brick will be capable of taking up more heat and the consequent outgoing gases will be lowered in temperature, the B.t.u's in the gas being absorbed by the brick and given off to heat the blast rather than wastefully being allowed to escape.

From rough calculation an increase of every 100 deg. in the stack temperature means approximately a consumption of ten percent more gas with very little increase in the resultant blast temperature.

The reason the same stove will give more or less heat at different times is due I believe principally to the change in the composition of the gas, the condition of the brick work and the length of time the stove has been on gas; and but very little to the number of cubic feet of gas that is burnt in it, considering that the proper amount is burnt when the temperature showed the lowest.

Of course difference in the amount of wind blown through a stove makes a vast difference in the blast temperature produced by the same stove, as the less wind passing through the stove the slower it will move and the more time it will have to absorb the heat from the brick work.

Another part worthy of note in stove construction is that the smaller the checker opening the faster the gas will give up its heat to the brick and the faster also the brick will give up its heat in turn to the blast.

All of the points especially noted from Mr. Diehl's paper are well known and are not advanced as any new theories or ideas but are to emphasize them as I think they are at times overlooked.

There is one point in Mr. Diehl's data which I do not just understand and that is how he can have so much *CO* and Oxygen at the same time in his flue gases. I can only explain it by thinking the cold blast valves must have leaked some air which at the low temperature at this point would not have combined with the *CO* to produce combustion.

Mr. J. A. Mohr:* The writer of this paper has so ably and plainly covered the subject of "Regenerative Stoves and Their Relation to Blast Furnace Practice" that he has opened many avenues for discussion, but the one in which I think we are most interested is the efficiency in practice.

Since the gas engine and low pressure steam turbine have come into use for power development, and in view of the increasing cost of fuel from year to year, blast furnace gas, the fuel for the stove, must no longer be looked upon as a waste or comparatively useless medium.

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It is quite evident therefore that the stove holds a very important relation to economical blast furnace practice. While it is generally accepted that the stoves require about one-third of the total gas produced by the furnace to provide heat for blast, this varies greatly with the type of stove, and in many cases I have reason to believe it is much greater than this amount. I quote from a recent number of *Stahl und Eisen,* of June 22nd, 1911, on "Importance of Power Derived from Blast Furnace Gas", where the statement is made that in German practice various plants estimate from 35 to 60 percent gas consumption for stoves, due to various types of stoves used, quality of gas, and other local conditions. With average conditions, they claim 45 to 48 percent consumption, with moisture in gas ranging from eight to twelve percent by volume.

My direct experience has been confined to the three-pass type of stove. By tests made on newly lined 21 by 100 ft. stoves, having a heating surface of about 47 500 sq. ft., we obtained an efficiency of 64 percent, using ordinary furnace gas having an average analysis of 13.5 percent CO_2; 22.73 percent CO; 4.04 percent H_2; 59.73 percent N_2 and 85.66 B.t.u. Stack gases 1.13 percent CO; 16.73 percent CO_2; 5.84 percent O_2; 76.30 percent N_2 and 3.62 B.t.u.

I affirm the writer's opinion regarding large heating surfaces, and would advocate no less than 200 000 sq. ft. for a 22 ft. 0 in. bosh furnace for the reasons he clearly mentions, advising the use of cleaned gas for all stoves.

The effect of flue dust upon the thermal efficiency of hot blast stoves is thoroughly discussed in a paper by B. H. Thwaite in the *Journal of the Iron and Steel Institute,* Vol. 63, Page 246.

During the eighties, when hard ores were in general use, such a thing as stove cleaning was practically unknown. But during the present era of Mesaba ores it is a common occurrence to find checkers clogged up if the stoves are not properly taken care of by cleaning them regularly about every five months. This expense need not be incurred if we use cleaned gas, dry cleaned gas being preferable on account of the additional sensible heat, providing the dust content can be reduced to a maximum of 0.25 grains per cu. ft. This, of course, can easily be

obtained by scrubbers, using water for washing, but the sensible heat is lost, and in many instances difficulty in burning the gas arises, due to the excessive amount of moisture carried by the gas under certain conditions.

All tests of the products of combustion of blast furnace gas shows the presence of O_2 and CO, indicating an incomplete combustion, due probably to incomplete mixing or stratification. This condition might be compared in a way to the trouble experienced in the early days of natural gas for domestic and industrial consumption. The high pressure of the gas caused much difficulty to effect a good combustion mixture, exemplified clearly by the deposit of carbon too often noticeable on a burner which was not properly designed to mix the gas with sufficient air.

In this connection for clean gas burning, a mixing burner should be designed to mix pre-heated air thoroughly with the gas. By this means, less excess air would be required, and the combustion temperature would be higher. As yet this burner has not been developed for stove use.

It seems very encouraging, in many cases to expect double the life of a hot blast stove using cleaned gas than one using ordinary dirty gas. Cleaned gas will preserve the draft of the stove, which has everything to do with its capacity, as its power is a measure of the quantity of fuel that can be consumed in the stove in a given time; hence an increase of the heat absorbed, other conditions being equal.

In regard to stacks for stoves, I do not find it the case with our three-pass stoves that the draft is impeded by cooling of the stack during the time that the stove is on the furnace, and favor individual stacks for three-pass stoves, moreover the best and most uniform draft is obtained in stoves with a central combustion chamber and having stacks arranged central on the dome. This is quite evident from the fact that the first three-pass stoves built had side combustion chambers, and in most cases offset stacks, which were later, for varions reasons, improved to the present type.

For two-pass stoves I think that one stack, centrally located, for one set of stoves, is more satisfactory than one for two sets,

for the reasons mentioned, and would not advocate the use of individual stacks at all, because the individual stack on a two-pass stove is of necessity very much longer than for a three-pass stove, and the cooling effect, I believe, would be detrimental to the draft of the stove.

I might mention that the last two stoves built at Carrie Furnaces were of the three-pass Massick & Crook type, 22 ft. diameter and 90 ft. high. A vast improvement in the sub-structure of the stove was made to carry the checkers so that the pressure per square inch on the lower walls carrying the checkers was reduced 24 percent, and checkers on the third pass arranged to provide additional surface, the total heating surface being 50 737 sq. ft. By actual trial after having been in use a short time and using ordinary dirty gas these stoves showed a performance of 1300 deg. Fahr. blast temperature constantly for two hours by adjustment of the equalizing valve during this space of time on a volume of about 33 000 cu. ft. of air.

We have never had any trouble with our stoves cracking between the second and third passes sufficiently to reduce the efficiency, and in general they have done exceedingly good work, being able at any time to carry from 1200 to 1400 deg. Fahr. for one hour, with a drop ranging from 75 to 150 deg. Fahr.

The only trouble of consequence developed after a life of nine years on our 21 by 100 ft. stoves. The walls carrying the checkers began to crush and crack, due to excessive weight of checkers. This led to the improvement in the last two stoves built mentioned above.

I do not favor an extraordinarily high stove. Best practice is slightly larger diameter and less height, and strongly advocate large heating surface with the use of cleaned gas.

In conclusion would say: First, that in general with the increased use of Mesaba ores, efficient furnace practice demands stoves which have relatively a large heating surface, say a ratio of 1¼ sq. ft. of surface to one cubic foot of air blown under normal conditions. Second, the use of clean gas. Third, more attention than heretofore should be given to the proper economic combustion of the gas.

Mr. A. E. Maccoun:* In my discussion of Mr. Diehl's very interesting paper on "Hot Blast Stoves in Relation to Modern Blast Furnace Practice", there is nothing in his paper that I wish to take exception to in any way, all I wish is to say a few more words relating to some of the important economies he has brought out in his paper, as I know all practical blast furnace men are very much interested in this subject.

In the lower part of a blast furnace, carbon is only oxidized to carbon-monoxide (CO), which generates 4376 B.t.u's per pound of carbon, but when complete combustion to carbon-dioxide (CO_2) takes place 14 580 B.t.u's are generated. Therefore, the heat generated by a unit of carbon in heating the blast is three times as great as that generated by a unit of carbon burned in the blast furnace.

The use of hot-blast increases the temperature and efficiency of combustion near the tuyeres of a blast furnace and causes the carbon to be quickly converted into carbon-monoxide and also localizes the heat of combustion. On account of this localization of the combustion, a smaller quantity of blast is required, the upper part of the furnace is cooler and less sensible heat is carried away in the escaping gases.

The diminished amount of fuel required by the use of high heats causes less ash from the fuel to be converted into slag, less limestone is required for fluxing, a furnace of a given capacity contains more ore, and its production is therefore increased.

At the present time in this country, every blast-furnace manager is trying to obtain all the advantages possible, such as better quality of product, lower cost of production and a larger tonnage, by the use of high heats, but it has been pointed out there is a limit as to how far this can economically be carried out.

With some furnaces having bad distribution, badly worn lines, etc., it is found impossible to make use of high heats, such as 1200 or 1300 deg. Fahr., and obtain these greater economies, but with well-proportioned furnaces in this respect, in good condition, these heats can be easily carried most of the time and

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the economies effected. But it must be remembered, as Bell said, that the quantity of carbon present in the furnace must always be sufficient to maintain a reducing action in the gas produced by the oxidation of the coke at the tuyeres. It is, therefore, only when the coke consumption exceeds the limit supposed to be essential for this object that the use of more heat can be beneficial to any great extent.

There is a definite amount of fuel gas passing off from a blast furnace, corresponding to its fuel consumption, which has a definite fuel value. This gaseous fuel has a much greater fuel value than an amount of coal containing an equal number of B.t.u's, as it does not require the expense of handling, and it is an ideal fuel on this account for use in hot blast stoves, gas engines, or for use under steam boilers in generating steam.

On this account we naturally wish to burn this fuel very economically in our stoves, so as to conserve as much as possible from the balance of gas left over for other useful purposes. It is for this reason blast furnace operators are giving so much thought to the design of the most economical stove possible to fulfill these conditions.

There are many types of stoves, such as the two-pass, three-pass and four-pass, which give excellent results when well constructed. Mr. Diehl has gone into this matter, also the importance of equalized draught, and I do not wish to go into the design of hot blast stoves at this time. The problem is to get as simple a stove as possible, having the required strength, with the greatest amount of well-arranged heating surface, so that all the heat possible will be absorbed from the passage of the burnt gases through its checkers and that this heat will also be readily given up to the air during its passage through the stove. To better obtain these results the tendency is to decrease the size of checker openings and most of the newer stoves have six inch checker openings in place of the customary nine inch openings. Mr. Diehl gives an example of a stove 22 ft. in diameter, 100 ft. high, that has 60 000 sq. ft. of heating surface. A modern blast furnace with an equipment of four well-designed stoves of this kind should have no trouble in running on a straight line heat of 1200 deg. Fahr. and still have plenty of reserve in

case it is demanded by the furnace, and the average stack temperatures from such stoves should be below 400 deg. Fahr., and it should not be necessary to install five stoves in place of four if washed gas is used.

Mr. Diehl has also pointed out the trouble incident to the use of dirty gas in stoves and this trouble increases with the use of very fine ores. I do not think he has brought out, as fully as he might, the advantages of gas-washing for stoves.

The blast furnace gas used for stoves should by all means be washed, but it is also advisable to first take out as much dust in the dry state as possible as this is valuable material and can be used over again in the furnace. By elaborate dry-cleaning alone it seems impossible to get the gas much below 0.5 grains of dust per cubic foot. By making an easy calculation it can be seen that this means a good deal of dust is passing through the stoves. Gas of this kind is not sufficiently clean to get the desired results from stoves.

Many methods have been brought forward for cleaning gas, such as dry-cleaning, contact washers depending on a large flow of gas striking a water surface, and spray washers similar to the type mentioned by Mr. Diehl.

As mentioned before, it is advisable to carry the dry washing far enough to take out the greater part of the coarser dust and cool the gases to some extent. After this it looks as if the spray type washer is the simplest and most efficient type for primary washing to remove the very fine dust. This of course means that the gas must be cooled down to at least 90 deg. Fahr. to prevent excessive moisture being carried over into stoves.

In no case do I believe contact washers are very efficient, because if they were efficient in removing dust a great amount of steam would naturally be developed, due to the high temperature of the gases passing through, and this steam would be carried over with the gas to the stoves, greatly reducing their efficiency.

A blast furnace that has four clean stoves and uses dirty gas can obtain excellent heat for a short time, but gradually the checker openings begin to clog up with dirt, bridge over the top and the heat begins to run down quickly, the efficiency of burn-

ing the gas in the stoves also drops, the furnace starts to do poorer work, then when stoves are taken off, one at a time, for cleaning we are still compelled to run on lower heat and the furnace gives still poorer results. After the cleaning of the stoves it is necessary to get the furnace used to taking the high heat again, and soon this operation has to be repeated. The eight percent gain in efficiency which also allows for the loss in sensible heat by washing and which was obtained on similar stoves with the same size checker openings, that Mr. Diehl mentions as resulting from the use of washed gas, is not at all representative of the actual gain to the blast furnace by the use of washed gas.

With washed gas, smaller checker openings can be used and greater heating surface obtained, we do not blow the amount of dust through hot blast valves, pipes, tuyeres, etc., and they are not cut so badly nor is nearly the amount of costly repairs required on this equipment or on the linings of the stoves themselves. We can also get perfect combustion with clean gas and have a uniform heat at our command at all times for the blast furnace. These results would be an impossibility to obtain with dirty gas, due to its filling up the stove wells with clinker which is nearly impossible to remove and which injures the walls of the combustion chambers and the efficiency of heat absorption and of the entire brickwork of the stove.

Most of the burners used on hot blast stoves in this country are very inefficient, and there is considerable room for improvement in the design of stove burners, so that a better mixture of air and gas will be obtained, together with arrangements for adjusting this mixture.

I trust these brief remarks may help to bring before you some of the important points taken up by Mr. Diehl in his interesting paper.

Mr. C. S. Forkum:* In Mr. Diehl's paper, his explanation of the decrease in coke consumption due to hot blast stoves is very good. I think there is also another explanation of this saving.

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When we calculate the saving in pounds of coke per ton of pig iron for an increase of 100 deg. in heat we must look for other reasons for this saving.

If we assume 40 000 cu. ft. of dry air per minute blown into a furnace making 480 tons per day, the addition of 100 deg. of heat will give

$100 \times 40\,000 \times .0761 \times .237 = 72\,142$ B.t.u. The furnace makes one ton of pig iron every three minutes; then $72\,142 \times 3 = 216\,426$ B.t.u. per ton of pig iron due to 100 deg. increase in heat.

If we assume 15 000 B.t.u. per pound of coke then $216\,426 \div 15\,000 = 14.4$ pounds of coke as the saving for 100 deg. increase in heat.

We know that for each 100 deg. increase there is a saving of about 50 pounds of coke per ton iron. This greater economy than the simple calculation shows, is to me very satisfactorily explained by the Theory of Critical Temperatures. This theory has been propounded for many years by various individuals, and enlarged upon by Prof. H. M. Howe. It is clearly set forth in the *Iron Trade Review* for January 2nd, 1908, in an article by John J. Porter, Ass't. Prof. of Metallurgy at the University of Cincinnati. The article points out that all heat processes in which heat is derived from heated gases are divided into two classes, namely: those having a critical temperature and those which do not have one.

In the simple transfer of heat from one object to another, all that is necessary is a difference of temperature. It is of secondary importance how great or how little is this difference, as long as the temperature of the heating agent is to some degree greater than the temperature of the object which is to be heated. Such a transfer of heat does not involve a critical temperature, and the efficiency of this heat process is almost independent of the initial temperature or temperature of the heating agent. Thus if it is desired to heat steel in the soaking pits to the melting point, say 2700 deg. Fahr., but not melt it, all that is necessary that the hot gases develope heat at a temperature but slightly in excess of 2700 deg. Fahr., and no matter how long the steel is exposed to that temperature it will not melt. If the steel is to be melted, then the process involves a critical tem-

perature. In order to melt it, heat must be supplied above the melting point, that is above 2700 deg. Fahr., in order to supply the Latent Heat of Fusion. Thus to melt one pound of steel, assuming the melting point at 2700 deg. Fahr., it would require 79 B.t.u. supplied at a temperature above 2700 deg. Fahr. after the steel has been heated to that temperature. Now it follows that a few degrees above the critical temperature exerts a very great influence upon the efficiency of this critical temperature process.

If we assume the temperature of the heating agent to be 2701 deg. and its specific heat 0.2 then the only heat that is available for melting the pound of steel is that supplied above 2700 deg. Then $(2701-2700)\times 0.2=0.2$ B.t.u. is the quantity of heat that one pound of the heating agent will furnish to melt the steel. Then since it requires 79 B.t.u. $79\div 0.2=395$ lb. of heating agent necessary to melt one pound of steel.

The total heat in 395 lb. of heating agent at 2701 deg. is: $395\times 2701\times 0.2=213\,379$ B.t.u.

And to melt one pound of steel (spec. heat 0.1)$=2700\times 0.1+79=349$ B.t.u.

$349\div 213\,379\times 100=0.16$ precent efficiency.

Now if the temperature of the heating agent be increased to 2710 deg. then

$(2710-2700)\times 0.2=2$ B.t.u.

$79\div 2=39.5$ lb. of heating agent.

$39.5\times 2710\times 0.2=21\,409$ B.t.u. in 39.5 lb. of heating agent. Then $349\div 21\,409\times 100=1.63$ percent efficiency.

It therefore may be seen that while the temperature of the heating agent was increased only 0.33 percent, the efficiency of the operation was increased over 10 percent. Now if we apply the foregoing to the blast furnace we can perceive wherein lies the economy in the use of hot blast over cold blast.

In referring to the desirability of high heats I think that all the heat that your stoves will economically produce, with the exception of 200 deg., should be carried on the furnace. The available 200 deg. is a reserve agent to fall back on to preserve the quality of the iron.

The Germans have made a table in which they give a value in pounds of coke per ton of pig iron for each 100 deg. increase in temperature above 1000 deg.

From 1000 to 1100=50 lb. coke
1100 to 1200=40 lb. coke.
1200 to 1300=30 lb. coke.
1300 to 1400=20 lb. coke.

There is reached however a point in the neighborhood of 1400 deg. above which it is not advisable to go because the saving in coke does not offset the wear on the stoves accompanying the intense heat and furthermore it becomes necessary to burn so much gas to maintain an additional 100 deg. in the stoves above that temperature, that in comparison to the benefits derived, it is found to be more economical to use the gas for other purposes.

Experience has shown that clean gas is more beneficial to furnace operation than dirty gas. I have found that 1300 deg. can be carried very nicely on stoves that have never used dirty gas, and about 1100 deg. is about the limit for stoves using dirty gas. It is very hard to keep the stoves clean and in good shape without considerable loss in time and money. Stove operated on dirty gas for two months barely yield 900 deg.

If we calculate the difference in heat absorbed by 45 000 cu. ft. of blast per minute at 1300 deg. and at 1100 deg. it shows an efficiency of 16 percent higher in the one case than in the other, both stoves using the same amount of gas.

Stoves tested at one plant I know of show 47744 cu. ft. gas per ton iron used in the stoves. The saving by having cleaner stoves, would amount to 7701 cu. ft. of gas per ton iron. This gas, assuming 90 B.t.u. per cu. ft., when used under boilers of 50 per cent efficiency will transfer to the boilers 346 545 B.t.u. If we assume a value under the boilers of 7200 B.t.u. per pound of coal then

346 545÷7200=48.1 lb. of coal. At $1.00 per ton=0.0215c per ton of pig iron.

At one plant using a Mullen washer the labor for cleaning stoves amounted to 60 hours per week or $9.60, and at another furnace not equipped with a gas washer was 120 hours or $19.20. The efficiencies of the stoves were maintained about equal. The

saving in labor, if this cleaning could be done away with, would be 0.0035c in the case of the Mullen washer and 0.0071c in the other, figured on an output of 450 tons of pig iron per day. These savings though small, if added together would amount to quite a reduction in cost of manufacture.

Any line of work that will reduce the cost of pig iron is of great interest to all furnace managers, and I think the hot blast stoves hold forth many possibilities not yet considered.

Mr. John I. Souther:* Mr. Diehl has so ably presented his paper that I think it requires no criticism whatever. He covers the subject in full. In going over the subject I noticed at the time of the introduction of hot blast, furnace practice was very poor. In fact, over eight tons of coal were consumed per ton of pig iron, the coal being coked in the open air. When they put on the hot blast they reduced that to about five tons of coal. Afterwards, when the hot blast was increased it was decreased to a little over two tons of coal per ton of pig iron. It seems to me at the same time there must have been a very rapid increase of the efficiency of the blast furnace. At this time when the Scotchmen were using eight tons, the Welch were using about three and the French were using only about two and a half tons of coal per ton of pig iron. The point that Mr. Diehl makes in regard to the efficiency of the hot stove is true, that the actual saving is much greater than is apparent, which seems to me to be fully brought out by some of the late writers. One writer refers to the critical temperature of iron melting, making comparison with water. He says that no matter how much heat one might expend, any quantity of heat would not boil water if the source was only 200 deg. Fahr. On the other hand, if it was 212 deg. one would boil some water. If it was 213 deg. more water would boil. If it was 220 deg. you would increase it say 19 points which would be 1900 percent more efficiency than it would be at 213. I think the same thing applies in blast furnaces. There is a certain amount of heat required to melt the iron. If you don't have that much heat it don't matter what amount of heat you put into it, it will produce no results. After

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you get above 2700 or 2800 deg. every degree above that will produce a certain effect and the percentage will be very much greater for every few degrees of increase. Mention has been made about losses and leakages in blast furnace practice. There are a good many blast furnace men here and I would like to know what they would consider "good practice" on loss and leakage. I would like to know the extent of leakage that should be permitted and would be called "good practice." I have never been able to pin anyone down definitely on this point. Now, in regard to the stove draft, which in this case is mostly down draft, it doesn't bear out the theoretical idea, usually taught. In speaking of a 2-pass stove with a single stack of its own, Mr. Diehl reports that the flues towards the stack will fill up more rapidly with dirt than those further away, which would show that there was more gas going down those flues than the others. In the 2-pass stoves, the gas goes *down* the second pass and, naturally, heat rises. It was therefore brought out in treating the theory of some blast stoves, that suppose the temperature of one of the checkers is 600 deg. and of the other is 400 deg. there would be more upward tendency on the 600 deg. checkers than the 400 deg. checkers and therefore the flue gases would seek the colder chamber, as there would not be so much resistance at that point, but this practice does not seem to bear out what I would think would be the theory. Mr. Diehl's practice is against that theory. The matter of efficiency loss is something that should be given more weight. I believe you people in the Pittsburgh district are far ahead of us as well as the people further east. There is one point that I would like to have a little more information on. The efficiency of the stove is increased eight percent by clean gas over dirty gas. Does that mean that with a stove giving 1200 degrees of heat using dirty gas that we can get 1300 degrees of heat, eight percent addition, by using clean gas, or do you simply use eight percent less gas?

THE AUTHOR: I would like to say in answer that the eight percent increased efficiency which we get is obtained by comparison of two tests from two stoves, or rather the averages of a number of tests. The thermal efficiency is higher in one case

than the other, principally on account of lower stack temperature and better combustion, more dense gas and lower moisture, also the better control in burning.

MR. J. I. SOUTHER: Would you get a higher temperature?

THE AUTHOR: Yes. Although the gas loses its sensible heat by being washed, this is partially repaid by the removal of some moisture, but the utimate result, taking clean brickwork, better combustion, lower stack temperature, etc., will more than overbalance the loss and show the efficiency as given.

MR. J. I.SOUTHER: The eight percent seems to me to be very low. Occasionally a furnace will be working very smoothly and the gas will be very much cleaner for some time, and I would say the efficiency was much greater than eight percent between the dirty and clean gas.

PROF. FREDERICK CRABTREE:* I regret very much that the copy of Mr. Diehl's paper was received too late to allow the preparation of a written discussion of it. As a matter of fact, I was not able to finish reading it until after arriving here this evening, so I do not feel able to add much of value to a paper so complete in itself, or to the comments of Mr. Messler, Mr. Mohr, Mr. Souther, Mr. Maccoun and others, who are much better fitted by experience than myself to discuss it. The paper is of much interest to one in my line of work, and will be of real value to everybody interested in hot blast stoves on account of its clear statement of the various requirements that have to be considered in the design, by stimulating thought on, and discussion of these points, and through the very full and instructive tables of results and calculations which are included.

There were two or three statements that particularly attracted my attention. Mr. Diehl mentions the attaining of gas composition showing 20 percent of CO to 15 percent of CO_2 as being a frequent occurrence. Most of us can remember the time, and it was not so very long ago, when the production of such a gas for any considerable portion of the time in regular practice would have been considered quite remarkable. Mr. Diehl's remark shows how quickly one who does not keep closely in

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touch with current results becomes "out of date". Yesterday, in going over a paper by Mr. B. H. Thwaite, published in the *Journal of the Iron & Steel Institute* for 1903, it was noticed that he gives an analysis of blast furnace gas (in English practice) showing 30 percent CO and nine percent CO_2. We certainly would consider that as extremely bad practice in this country. Undoubtedly it would be unfair to consider Mr. Thwaite's analysis as being typical of good English practice; and 20 percent CO to 15 percent CO_2 can hardly be considered as representative of the average American practice. But to have it mentioned as being of frequent occurrence is noteworthy.

One of the interesting features of Mr. Diehl's paper is his comparison of the two-pass and three-pass stoves. A man who has had experience with only one kind of stove naturally desires to know how it compares with other kinds. We read frequently of the very fine results being obtained with the three-pass stoves; but direct inquiries addressed to superintendents who have had experience with them brings out contradictory replies, and show that there is no uniformity of opinion as to the comparative merits of the two types. One man says he can always depend on getting a higher heat from a three-pass stove; the next man is equally positive that the two-pass stove will give just as much heat, and with some advantages in other ways. Mr. Diehl is fortunate in having three types of stoves to study at the same time, but he diplomatically avoids advocating either the two-pass or the three-pass type, stating that each gives first class service.

As regards the comparison between washed gas and unwashed gas, the figures given in Mr. Diehl's tables are not as striking as might have been expected. It is true that the average efficiency, or the average percent of heat absorbed by the blast is 4.4 percent higher for the stoves using washed gas than for the stoves of the same type and size using unwashed gas; but the conditions of the experiments varied materially and in some cases the stoves on clean gas gave results considerably lower than the average of the stoves on unwashed gas. A simple comparison of thermal efficiencies for tests under quite diverse conditions is not a fair basis for judgment. In the case of the four tests on unwashed gas, of two-pass, center combustion stoves, the

volume of gas burned was too great to give the best thermal efficiency; but the practical results—the temperatures of blast obtained—were remarkably good.

Probably every man who is responsible for the actual operation of hot blast stoves is firmly convinced of the advantages of washed gas, and would unhesitatingly prefer it. But Mr. Diehl's tables emphasize the difficulty, occasionally experienced, of proving by actual figures what seems to be plainly evident.

Mr. Harry Kennedy:* I feel very much out of place to talk on a subject that has been discussed so thoroughly. I am reckoned among those unfortunate people who have had to serve out the majority of their lives in the operation of blast furnaces, and naturally I have learned something in regard to the relation between the stoves and the furnace. There are a few things that seem important to me in relation to this work. I would say that gas which is being consumed in the stove has a great tendency to deteriorate the whole structure, and the recommendation is that the gas should be washed. The expense is a factor. Most everyone would like to have clean gas, but I have found that the large majority of men are not willing to spend the money to get it clean, if they knew how. There are methods whereby it can be cleaned, and the principal objection to the dirty gas is that the gas passing into the combustion chamber carries with it bases which are not found so much in the Lake Superior ore as in other ores. Fusing of the brick work is undoubtedly begun by the bases that are being furnished to the acids and it is quite possible to melt the combustion chamber out of the stove, and when the door is opened the mass runs out like molasses.

The next thing that I would say in reference to the stoves is that the checker work should be set on durable foundations. I have found in most constructions of stoves that the checker work was set on foundations that were of a very flimsy nature and these stoves, when they begin to get loose at the bottom, allow the checker work to sag and the whole apparatus begins to loosen up. It is very difficult to shore up checker work and maintain stoves that have not been laid on good foundations.

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The upkeep of the stove at that particular point as well as at the top on the three-pass stoves are very vital points. Three-pass stoves have a great tendency for the inner dome to sag.

Prof. Frederick Crabtree: There is one point that might possibly have a little bearing on stove construction, it seems to me, and which has not been mentioned tonight. Recently, I noticed an article, published sometime ago, on the thermal conductivity and heat transfer of fire clay products, giving the results of an elaborate series of tests which were made. I believe, in France. As I remember it, the statement was made that the heat conductivity of fire clay, fire brick, and other clay products differed only very, very slightly provided the products were all made in the same way and burned at the same temperature in the original burning; but that if the brick or clay was burned at different temperatures there were very noticeable differences in conductivities. If this is true, might there not be a possibility of noticeably varying the heating capacity of a stove by some control in the making of the brick. It would be interesting to know, perhaps, to know just what investigations have been carried on by such a concern as the Harbison-Walker Refractories Company, who are very progressive along such lines.

Another particularly interesting point about which nothing has been said, and which is a feature of importance in stove design is the relation of the volume of brick to the heating surface—or to put it more accurately, perhaps, the minimum thickness of brick that is necessary in the checker work. It was reported years ago that the German engineers had declared the familiar hexagonal, cylindrical hole brick to be inefficient, owing to the excessive amount of brick for the heating surface exposed. The tendency now, of course, is to use smaller checker passages, and thinner walls. It would be interesting to know the data on which the choice is based, and what is the wisest limit to this reduction of thickness. Experiments begun some time ago at one plant and discontinued on account of press of other work, showed that at certain points in the brick work of the stove, there was little or no change in temperature at any time during

the three hours of burning gas. Evidently such brickwork was not doing anything toward heating the blast.

Mr. J. W. Dougherty:* I have listened with a great deal of interest to Mr. Diehl's paper and the discussion presented this evening and there is one phase of the subject, the proper number of stoves with which a blast furnace should be equipped, which has not been discussed, except for Mr. Maccoun's statement that he thought four stoves were sufficient for a single blast furnace. A great many blast furnace engineers and blast furnace managers seem to think that a modern furnace should be equipped with five stoves. This, in my judgment, is a mistake. If a furnace is equipped with four stoves properly designed and properly built, there is no doubt but what 1400 to 1500 deg. Fahr. can be obtained in the blast continuously, should the furnace be able to use this high blast temperature. With a mixture consisting mainly of hard hematites or magnetites, there is no doubt but that 1400 deg. can be used continuously, for this temperature of blast is the common practice in German blast furnaces. I do not think blast furnace engineers have given the question of the heat radiation from the outside of the steel shells of the stoves as much consideration as the subject deserves, especially when the economical production of iron with the lowest cost of manufacture is carefully considered. With five stoves, as at present constructed, there is, without doubt, more heat radiated from the outside shell of the stove; the more stoves, the more heat lost in radiation, and for this reason I am inclined to think that if three stoves were properly designed, particular care being used to see that the combustion chambers were sufficiently large, and built to contain the total amount of fire brick heating surface which is contained in five stoves, as at present specified, and if the three stoves were erected with a satisfactory non-conducting heat material on the inside of the shell to prevent the heat getting to the shell, that maximum of economy would be secured in the use of blast furnace gases for heating the stoves.

In Belgium and Germany an infusorial earth is used to

*President, Pittsburgh Crucible Steel Co., Oliver Bldg., Pittsburgh.

manufacture bricks which are used for outside walls of steam boilers, and I am told that if a man lays his hand on these outside walls, even though 1000 boiler horse power is being developed in a single unit, that he will find the outside walls are almost as cool as the brick walls of a dwelling house.

In my judgment, as stated before, some material which is a non-conductor of heat, should be used between the steel shell and the fire brick work to give radiatory conditions similar to those obtained in German and belgian boiler construction.

A stove should be built so that the gas, instead of being burned in the checker work, would have its combustion completed in the combustion chamber, and the checker chamber should simply be used as a reservoir for the heat. Especially should this be the case if dirty gases are used, as the dirt accumulates on top of the checkers and cinders so hard that it is difficult to remove.

The question of placing an auxiliary chamber on the outside of each stove, in my judgment should be considered, if gases containing much dust are used. My idea is that a portion of the gases should be burned in this chamber; the other portion being burned in the main combustion chamber, and that no combustion takes place in the top of the checker work. With the auxiliary chamber when the gases are first burned, a good portion of the dirt contained in the gas is dropped in the chamber and it is a much easier matter to clean this chamber than it is to remove the dirt from the top of the checkers. The auxiliary chamber can be cooled off very readily in a half day, whereas, if it has to be removed from the top of the checkers, especially in three pass stoves with the draft stack on the top of the stove, it will be four or five days before the stove will be sufficiently cool to permit a man getting into the top to work safely.

I make these remarks for the purpose of drawing a discussion, and with that in view, would like to have some of the different furnacemen present this evening, give their views on this phase of the stove question.

Mr. Kenneth Seaver:* In the very interesting paper and discussion we have heard this evening, the question of flue area

*Chief Engineer, Harbison-Walker Refractories Company, Pittsburgh.

has had much consideration and it is of course a most improtant one. But what has not been discussed is the question of the volume of the brick work and of course its specific heat, matters vitally connected with the efficiency of the stove and its satisfactory operation.

To reduce it to an extreme, there might be an enormous amount of flue area—of heat radiating surface, yet with such a small mass of fire brick as to store up an entirely inadequate amount of heat. The total amount of heat which can be taken on and given off is naturally dependent upon the mass of the fire brick and its specific heat, and the mass as well as the flue area should be considered in the design.

This question is closely connected with another which is recently receiving the consideration it has long deserved, namely, the proper thickness of the flue walls or checker brick; its design so that there shall be a maximum of heat radiating mass yet without any dead or at least comparatively inactive portion at its center.

In line with the remarks of Prof. Crabtree regarding specific heats and conductivity, I have read the article to which he refers with much interest. Those with whom I am associated have recently completed a long series of tests with the idea of determining definitely by practical experiment, whether the specific heat of various refractories was affected by any variation in grind or burn and found, as would have been expected, that the variation was less than the calculated probable error in the determination.

While such variations as indicated have a considerable influence on conductivity, the manufacturer is yet held within rather well defined lines due to the requisite physical structure of the brick.

In the particular experiments referred to by Prof. Crabtree the material was burned at such a low temperature as to preclude the possibility of getting a satisfactory bond and proper physical structure for actual working conditions.

Mr. J. M. Knote:* Theoretically the temperature to which a brick is burned should not affect its specific heat. The reason

*Assistant Chemist, Pittsburgh Testing Laboratory, Pittsburgh.

for this is that the specific heat of any material depends upon its chemical composition and as long as the composition is not changed the specific heat should remain unchanged, even if the material changes its physical form, that is from the amorphous to the crystalline condition. It would not make much difference whether the brick was made of plastic clay with no flint clay in it, or of a small proportion of plastic clay and a larger proportion of flint clay, because the difference in the chemical composition would be so little that the specific heat would not be affected materially.

The best way to get a high specific heat in a brick is to make it as dense as possible, thereby getting a greater weight of clay into it. The specific heat of clay does increase, however, as the temperature increases. At 100 deg. Cent. its specific heat is close to 0.2. This increases and has been determined as about 0.23 at 1000 deg. Cent. This behaviour, of course, is not peculiar to clay alone but to all materials.

In regard to the draft going to the hot part of a stove and avoiding the cooler parts as brought out by a previous speaker, I would like to remark that the path of flow for gases while passing down draft through checker work is determined primarily by the resistance offered. It will pick out the path of least resistance and stay there getting this part very hot and neglecting the cooler parts. If just the right flue area is provided to carry the volume of gases supplied, there should be no cool spots.

The Author: I would like to answer Mr. Dougherty in regard to the five stove equipment. In a plant of recent construction five stoves were advocated and built. I think the principal idea at that time was simply to furnish sufficient heating surface, and whether this could be obtained by three stoves or five stoves, I don't think it would make much difference as long as the proper combustion, and the proper distribution of the waste gases were conformed with. The radiating surface on three stoves would be less possibly than on five stoves. This applies only to clean gas where no stove cleaning work is needed. The question of oxygen and monoxide in the gas, comes up repeatedly. Analysis at the stacks generally shows the presence of both gases. We also often get the same condition in furnace

gas. Whether it is due to leakage is hard to tell. We sometimes say it is an error on the part of the chemist. The fact still remains that there is an economical point to which you can allow, the monoxide to show in your gas and still be more efficient in your operation than to have the large excess of air required to remove all traces of the monoxide. If the oxygen in the flue gas is running two percent you will generally find a trace of carbon monoxide. It may be due to stratification or some bad mixture at the bottom of the stove.

Mr. W. J. Dougherty: My idea is that with three large stoves, clean gas would be used.

Prof. Frederick Crabtree: I noticed with considerable interest in the paper that the specified amount of air blown into a furnace is between 36 000 and 40 000 cu. ft. of air per minute. If you visit a blast furnace plant and ask how much air they are blowing, they will tell you 42 000, 44 000 or up to 49 000 cu. ft. per min. They are speaking then of course of the piston displacement. It would seem that very few furnace men until within the last few years made any serious effort to find out the actual amount of air blown in. Mr. Diehl was referring to the actual air delivery I suppose, not the piston displacement. Some time ago I had occasion to make an experiment in an attempt to find out something along these lines. It seemed desirable to make an actual measurement, if possible, of the amount of air going into a furnace. After trying one or two ways I settled upon the throttling disc method, applied to the cold blast main. This method showed a volume of something like 35 000 cu. ft. of air per minute, calculated to 30 deg. Fahr. The piston displacement of the blowing engine at the time was 49 000. That was a pretty big discrepency but probably not greater than would be found at many plants. It is an almost universal custom to figure on piston displacement and not to attempt to find out what the actual delivery is.

The Author: I want to say in regard to air blown and piston displacement, that this question really has to be solved by each plant separately, taking their local conditions into consideration. Actual piston displacement, less the tub leakage and

clearance, also loss of air through leaks and released at the stoves, will give the best practical figure.

We have found that about 10 percent would cover this condition, and it has been our practice to make this deduction for leakage from the piston displacement which will include the losses in the stoves. These figures have been used to find the quantity of air blown per pound of coke. Leakage is a pretty hard thing to get at, and it would be impossible to lay down a rule which would be applicable to all plants.

Prof. Frederick Crabtree: I might say there is a method which, if you have the data, will give you correct figures for air going into the furnace. If you have true average analyses and weights of raw materials and true average analysis of the gas you can calculate the amount of air that is going into the furnace. In connection with the previously mentioned experiments by the throttling disc method there was made a calculation based on the records of the furnace for a whole month, calculating the total amount of ore charged, also soke and limestone, and making deductions for flue dust. Of course it was necessary to assume that the gas analyses were fairly representative. The gas samples had to be taken over a long period of time to be sure that they would be average samples. In that way there was found a very, very slight disagreement from the results by the throttling disc method. I think it was somewhere in the neighborhood of 34 800 as against 35 000.

Mr. R. H. Wilkinson, Jr.:* It seems to me that it would be illuminating if information were given as to the best coke practice at 800, 900, 1000, 1100 and 1200 deg., the best average for one month or six months.

The Author: During the month of October we had a furnace running between seven and eight hundred degrees of heat with the coke per ton of iron down to 2000 pounds. Another furnace was running on 1100 degrees of heat and it took 2300 pounds of coke per ton or iron. One furnace was in good shape and the conditions were such that the furnace would run very easy, while the other furnace was very heavy scaffolded.

*Superintendent, The Struthers Furnace Company, Struthers, Ohio.

It is pretty hard to say that if you only apply additional heat you are going to get the desired results. You must have your other conditions right also. When conditions of practice, material and equipment are such that a furnace will take heat, the higher blast temperature will give the most economical working, and a blast furnace should be equipped to take advantage of these conditions. There are very often times when far better results can be obtained by using low heat. After all, it is a matter of judgment of the furnace manager.

Mr. R. H. Wilkinson, Jr.: If you had put 400 degrees more heat to that furnace, would your coke have been below 1800, or 200 lb. lower which it should be theoretically?

The Author: I don't think so. Just at the time we were anxious to have the furnace working well and the furnace worked better with a low heat condition at that time with a greater quantity of heat. The heat now on that furnace is somewhat higher and the coke and practice is about the same, but I suppose if the furnace were cleaned we could use a higher heat. Unfortunately, the furnace has a poor stove equipment and is also running on dirty gas, so that we have to clean out the stoves frequently. The heat drops to 750 and 800 degrees, which would cause big variations in our heat practice if we attempted to take advantage of all the heat we could get.

Mr. R. H. Wilkinson, Jr.: I would like to ask whether the burden on that furnace was largely Mesaba and also what you slag volume was?

The Author: The slag volume was about 1100 and 1200 pounds per ton of iron, and the percentage of Mesaba about 80. The burdens remained the same on the furnace.

Mr. R. W. H. Atcheson:* I would think their coke consumption did not necessarily hinge on the physical or chemical composition of the ore. Since, with a plant of several duplicate furnaces, working identical ore mixtures from the same stock piles, we rarely get identical results. The quality of ore is important but, it seems to me, we look too closely at the ore mix-

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ture and furnace lines and do not sufficiently emphasize the effect that the rate of travel and changing locations and temperatures of the various zones have on the furnace reactions. With an old lining, if your furnace were working along efficiently and had the zones in definite locations and it became necessary to lay off stoves to clean or repair them you would get very decided change—more than the decrease in blast temperature would indicate. After a furnace adjusts itself to a certain thermal intensity, the working conditions are usually seriously disarranged by either a decided increase or decrease in the blast temperature.

For the benefit of those present who have had limited experience with actual blast furnace operating conditions, it seems it might be well to emphasize what has already been said comparing two-pass and three-pass stoves; that the chimney valves in three-pass stoves are a source of almost constant air leaks since they are suspended in the direct path of the hot stack gases while the external chimney valves on the average two-pass stove are easily kept tight. Another decided advantage of the two-pass is the accessibility of all checker work from the outside of the stove. By removing the side doors on top of the stoves the checkers can all be cleaned without going inside the stove.

Mr. H. C. Cronemeyer:* You spoke of separating the efficiency of the stove itself from that of the burner. I don't see how to do that except by the anaylsis of the stack gases, and I think a serious discrepancy might occur there and the efficiency of the burning could not be changed by the stratification alone. Do you use any other method?

The Author: We do not, but our cold air blast valves are tight so there would not be any chance of air leaking in to gas. We only determine this from our gas analysis.

*Efficiency Engineer, Jones and Laughlin Steel Company, Aliquippa Works, Aliquippa, Pa.

[A partial bibliography of recent literature on Regenerative Stoves is appended and it is desired to acknowledge the assistance of the Technology Department of the Carnegie Library of Pittsburgh in its preparation.—Editor.]

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Hartman, John M. & Kennedy, John S. Hartman-Kennedy Fire Brick Stove. 1,000 w. 1904. (In Iron Age, v. 74, Aug. 18, p. 6.)
Improvement consists mainly in an external, horizontal combustion chamber for the preliminary deposition of the flue dust.

Hartman-Kennedy Fire Brick Stoves. 1,000 w. 1906. (In Iron Trade Review, v. 39, pt. 2, Sept. 20, p. 27.)
Stoves are kept clean by use of dry dust-catchers and an external combustion chamber.

Hot Blast Stove. 800 w. 1909. (In Electro-Chemical and Metallurgical Industry, v. 7, p. 542.)
Describes and illustrates stove designed by Walter O. Amsler. Improved design avoids difficulties formerly met, owing to uneven expansion and contraction.

Moore Hot Blast Stove. 1,500 w. 1903. (In Iron Age, v. 71, Feb. 12, p. 10.)

New Development in Cowper Hot Blast Stoves. 1,000 w. 1904. (In Iron and Coal Trades Review, v. 69, p. 2027.)
Improvements are concerned with prevention of accumulations of dust and with increased facilities for rapid cleaning.

New Hot Blast Stove. 1,000 w. 1910. (In Metallurgical and Chemical Engineering, v. 8, p. 294.)
Describes stove constructed by Alfred C. Nelson, in the lining of which are used only such bricks as are listed in brick manufacturers' catalogues.

Osann, Bernhard. Die Berechnung Steinerner Winderhitzer unter Zugrundelegung des Warmeleitungs-vermogens Feurfester Steine. 8,000 w. 1909. ((In Stahl und Eisen, v. 29, pt. 2, p. 1060, 1107, 1147.)
Considers conductivity of fire-brick in Cowper stoves and methods of calculation of loss of heat from radiation.

Roberts Three-Pass Fire Brick Stove. 800 w. 1907. (In Iron Age, v. 79, p. 1879.)
Contains a cylindrical combustion chamber surrounded by four down-pass regenerators and four up-pass regenerators.

Separate Combustion Chamber for Stoves. 1,500 w. 1904. (In Iron Trade Review, v. 37, pt. 1, June 2, p. 77.)
Refers to patented improvements by A. P. Gaines.

Stevenson, John L. Designing and Equipment of Blast Furnaces—(hot-blast stoves.) 1,200 w. 1902. (In Engineer, London, v. 94, p. 248.)
Considers capacities, operating conditions, etc.

Thwaite, B. H. Effect of Flue Dust upon the Thermal Efficiency of Hot-Blast Stoves. 8,500 w. 1903. (In Journal of the Iron and Steel Institute, v. 63, p. 246.)
Favors the use of blast furnace gases for power purposes and the substitution of producer gas for heating the stoves.

ANNUAL MEETING.

The Thirty-first Annual Meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, January 17, 1911, at 8:15 P. M., President Morse presiding, 85 members and visitors being present.

The minutes of the last annual meeting, held January 19, 1909, were read and approved.

The annual report of the Board of Direction, including the reports of Standing Committees, Sections and the Treasurer, was read, as follows:

REPORT OF THE BOARD OF DIRECTION.

The Board of Direction of the Society held fourteen meetings during the past year at which the routine business of the Society was transacted.

Early in the year the inadequacy of our Auditorium in the Fulton Building became most pronounced and a special meeting of the Board was called, the Past Presidents of the Society being invited to attend, to consider the matter of remodeling the quarters then occupied, or moving to another building. After careful consideration of a number of sketches and plans which had been prepared, it was decided to lease our present quarters.

For the first time in a number of years a Membership Committee was appointed, and the results of this Committee's work have been most gratifying. The Student Grade of Membership, established early in the year has been cordially received by the advanced students in our local engineering schools.

The year has been marked by the active interest taken by the Society in public questions affecting the engineering profession.

During the year there were held nine regular, one special and the annual meeting of the Society. The average attendance was 117, an increase of 49 over the average attendance last year. The average number participating in discussion of papers was eight, the maximum attendance was 450 and the minimum 47.

At the close of the year the membership of the Society was as follows:

Honorary members	6
Life members	3
Active members	892
Associates	9
Juniors	50
Total	**960**

During the year there were:

Resignations	32
Removals by death	3
Dropped	3
Total	38
Accessions	163

The net increase in the membership of the Society for the year is one hundred and twenty-five.

REPORT OF HOUSE COMMITTEE.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

During the past year the Society moved into its present quarters, the tenth meeting place in its history. In arranging the rooms the Auditorium was given much consideration, being enlarged considerably over those in former quarters.

The belief that a more central location for the Society would be advantageous has been borne out by the increased attendance at the various meetings.

During the year the Auditorium has been used on 57 occasions, 21 times for Society meetings and 36 times for other organizations.

The Society rooms have been open on every Saturday evening until 10:00 o'clock, the total attendance being a little more than two. It is the belief of this Committee that much good would result if smokers were held in the Society rooms on one Saturday night in each month and beg to suggest this for the consideration of future Entertainment Committees.

In the early part of the year a new reflecting and projecting lantern was purchased, and after moving to our present quarters the seating capacity of the Auditorium was increased by the addition of fifty new chairs.

During the year several gifts have been made to the Society in the way of furnishings. The large American flag hanging above the rostrum is the gift of Mr. E. K. Morse and the three framed maps of the Connellsville Coke Region and the Pittsburgh and Fairmont Coal Districts are the gifts of Mr. James B. Hogg.

Respectfully submitted,

S. A. Taylor, Chairman.

REPORT OF PUBLICATION COMMITTEE.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

I have the honor to present the following report of the work of the Publication Committee during the fiscal year 1910.

The Committee has, to the best of its ability, executed the duties imposed upon it by the By-Laws. Papers have been provided for all meetings of the Society, and general supervision has been exercised over the publications. During the fall two evenings were devoted to addresses by non-residents and as these meetings were among the most popular, the Committee advises that the policy of having non-resident speakers at some meetings each year be continued.

The chairman wishes to record his appreciation of the valuable assistance given by the other members of the Committee and the Secretary, who have on all occasions given freely and effectively their time and labor to the affairs committed to them by the Society.

HARRISON W. CRAVER, Chairman.

REPORT OF ENTERTAINMENT COMMITTEE.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

During the past year four inspection trips have been provided in addition to the "House Warming" on the occasion of the opening of our new quarters in the Oliver Building. This latter was a social affair, the ladies of the Society adding largely to its success by their presence. An orchestra was in attendance at the supper served by the officials of the Henry W. Oliver Building and dancing was in order later in the evening. The attendance was 350.

The inspection trips made were as follows:

On March 26th to the Government Testing Station at Arsenal Park. The arrangements for this trip were very complete and the trip was a most instructive one. The attendance was 200.

On July 16th the Society visited the large reinforced concrete bridge at Meadow Street and the work embracing the repairs to 22nd Street Bridge. The attendance was 50.

On October 8th, by invitation of the officials of the Pittsburg-Buffalo Company, the Society visited the mines and town of Marianna. This was a most enjoyable affair and every facility was afforded the members of the Society and the ladies to visit the mine and other features of interest. Supper was served in the ball room of the Amusement Hall after which dancing was the order of the evening. The attendance was 335.

On November 5th, through the courtesy of the officials of the Jones & Laughlin Steel Co. the Society visited the extensive works of that company at Aliquippa.

The carefully planned itinerary led the members of the Society into every portion of the plant. The attendance was 258.

A prominent feature of the Society's affairs the past year has been the attendance of ladies which has led to their being invited to attend the annual banquet of the Society to be held on Saturday night. This is a marked innovation, but it is believed that it will prove a most happy arrangement.

Respectfully submitted,

S. P. Grace, Chairman.

REPORT OF FINANCE COMMITTEE.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

Your finance committee has made monthly audits of the Secretary's financial reports and are pleased to report that the Society is continuing on a firm financial footing as is indicated in Treasurer Frost's statement of the year's finances. It is very gratifying to report that in spite of the expense incident to moving to our new quarters, and of increasing the seating capacity of the Auditorium, the purchase of a new lantern and the necessary expenditures incident to the Society's activities in various lines of public good that we are not running behind.

Respectfully submitted,

J. N. Chester, Chairman.

REPORT OF MEMBERSHIP COMMITTEE.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

The Membership Committee formed by your direction in May, 1910 beg to report continuous activity since its organization. The number of accessions to the roll of the Society during that period is 135 compared with a total of 163 for the entire year.

In its work the Committee maintained the high standard of qualifications required under the By-laws by directing its efforts toward those eligible to Active Membership. An effort was made to impress upon the engineers of this community not affiliated with the Society that it is a privilege to belong to it, and that their names on the roll would indicate a professional standing all were bound to reach and maintain as a proof that they were expanding in knowledge and usefulness. The most efficient proselyting influence was found to

be the interest the members of the Society show in its Proceedings, and the credit they give it for increase of their own knowledge and capacity. Many members, who regularly attend the meetings, read and discuss the Proceedings, and exhibit to all with whom they come in contact the benefits they are receiving from the Society, brought in applications which were not solicited, but the result of a desire to share in these benefits.

The power for producing results in any line of human activity is largely measured by an evidence of sincerity and we wish to thank those who have so greatly aided the Committee by their sincere belief in the usefulness and value of their connection with the Society. We venture the hope that the movement will be continued, for there are many engineers in the community who have not yet been reached. A large number of students and recent graduates from engineering schools would greatly benefit from a connection with the Society, now so easily obtained under the amended By-Laws, and they would later form that class of active, earnest members whose ranks must be continuously increased if the Society is to attain the success and power its character and opportunity make possible.

Respectfully submitted,

SAMUEL E. DUFF, Chairman.

REPORT OF TREASURER.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

The Treasurer of the Society takes special pleasure in transmitting the following statement, as it is the 30th annual report he has made as Treasurer of the Society and in these thirty years has seen the receipts grow from about $1000.00 to over $12000.00, the net income from $168.73 to over $1100.00 and the cash assets from $187.88 to over $12500.00.

These figures indicate a careful business administration of the Society's affairs which is most gratifying.

INVESTMENTS.

Building Fund.

One, $1000 00 Butler Water Company, 6 per cent. bond, No. 9, matures September 2, 1931 ..... $1025 00

Permanent Fund.

Two, $1000 00 Connellsville Water Company, 5 per cent. bonds, Nos. 317-318, mature October 1, 1939 ..... 2020 00

Two, $1000 00 Portsmouth, Berkley & Suffolk Water Company, 5 per cent. bonds, Nos. 465-466, mature November 1, 1944	2000 00
One, $1000 00 Manufacturers Light & Heat, 6 per cent. bond, No. 4266, Series K, matures May 1, 1914	1010 00
Two, $1000 00 Jones & Laughlin Steel Company, 5 per cent. bonds, Nos. 3020-3021, mature May 1, 1931	1998 62

General Fund.

One, $1000 00 Jones & Laughlin Steel Company, 5 per cent. bonds, No. 3022, matures May 1, 1931	999 30
Total nine bonds	$9052 92

RECEIPTS.		EXPENDITURES.	
Dues, 1911	$ 91 50	Administration	$ 3,238 97
Dues, 1910	6,348 25	Entertainment	1,383 62
Dues, 1909	414 50	House	3,258 48
Dues, 1908	85 00	Library	92 60
Dues, 1907	32 00	General Society	840 05
Dues, 1906	16 00	Mechanical Section	110 96
Entrance Fees	800 00	Structural Section	92 66
Advertising	2,136 32	Proceedings	1,843 43
Interest	584 99	Advertising	15 00
Banquet	1,060 00	Miscellaneous	276 80
Sale of Proceedings	339 01		
Sale of Cuts	22 00		$11,152 57
Society Pins	60 00		
Rent of Auditorium	227 50		
Miscellaneous	72 93		
	$12,290 00		

TOTAL ASSETS.

	December 31, 1909.	*December* 31, 1910.
Bonds	$ 9,052 92	$ 9,052 92
Permanent Fund	1,591 44	1,655 72
Building Fund	510 55	531 15
General & Petty Cash Funds	219 27	1,271 82
	11,374 18	
Increase in Assets for 1910 over 1909	1,137 43	
	12,511 61	12,511 61

Respectfully submitted,

A. E. Frost, Treasurer.

REPORT OF MECHANICAL SECTION.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

During the past year five meetings of the Mechanical Section were held. The average attendance was 61, and the average number participating in discussions, eight. The maximum attendance was 76 and the minimum 30.

The following papers were presented:

"The Engineers' Society; Its Future," by Richard Hirsch.

"The Selection of a Boiler Feed Water," by J. C. W. Greth.

"Air Conditioning Apparatus," by W. H. Carrier.

"A Modern Central Heat, Light and Power Station," by W. G. Boyle.

"Two-Cycle vs. Four-Cycle Gas Engines," by E. J. Fithian.

In closing the eighth year of the Mechanical Section we are pleased to note that its work has maintained the usual high standard, even though the enthusiasm that marked the first few years of its existence has not been so pronounced. A Section of the Society has two chief missions to perform. It should consider in detail specific questions relating to engineering and it should encourage the younger members to take part in the discussions. With these two points in view it is believed that the Mechanical Section has a large field of usefulness before it, and the benefits derived by its members will increase year by year.

Respectfully submitted,

A. Stucki, Chairman.

REPORT OF STRUCTURAL SECTION.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

Five regular meetings of the Structural Section were held during 1910, at which one topical discussion and four papers were presented. The average attendance was 62, with an average of 10 taking part in the discussions. The maximum attendance was 122 and the minimum 30.

The following subjects were presented:

At the January meeting A. R. Raymer read a paper on "Masonry for the Ohio River Bridge of the P. & L. E. R. R. at Beaver, Pa."

At the March meeting the program consisted of a topical discussion on "Present Day Needs in Structural Materials," which was presented under subheads as follows:

"Road Materials," by S. D. Foster.

"Fire-proofing Materials," by C. B. Asher.

"Refractory Materials," by Kenneth Seaver.
"Timber," by E. F. Wendt.
"Steel," by R. B. Woodworth.

In this presentation the problems were stated and the solutions were left for discussion in future papers.

At the May meeting F. R. Babcock read a paper on "Lumber," treating of the sources and classification.

At the September meeting Charles M. Reppert read a paper on "Recent Retaining Wall Practice, City of Pittsburgh."

At the November meeting, the paper prepared by C. P. Winslow on "The Preservation of Structural Timber from Decay," was read by the Secretary in the absence of the author.

Each of the five meetings can be characterized as interesting and valuable to the members. At some of the meetings there seemed to be a hesitancy on the part of those present to express ideas at variance with those of the author. The real purpose of the Section cannot be attained unless the subjects are discussed from both standpoints. This can sometimes be accomplished by asking leading questions. It is hoped the members will be more active in this regard.

Three of the sub-topics considered at the March meeting have not yet been taken up for complete discussion, and under the general head of "Structural Materials," there are a number of other subjects which might be considered with profit. We would recommend that the program policy of the year be continued. Many subjects of vital interest to the members have not been treated before the society recently and it will be a great aid to the Executive Committee to have members call attention to these subjects with recommendations as to those capable of preparing papers.

Under the By-Laws, which went into effect in 1910, the arrangements for the programs for the Section were in charge of the Publication Committee of the General Society, with the Chairman of the Section a member of the Committee by virtue of his office. This has resulted in complete cooperation between the Executive Committee of the Section and the Publication Committee, and the plan seems conducive to the best interests of all concerned.

At the Annual Meeting, held January 3, 1911, the following officers were elected for the ensuing year:

Chairman: R. B. Woodworth.
Vice-Chairman: T. J. Wilkerson.
Directors: Edward Godfrey, Charles G. Schade, H. F. Layton.

Respectfully submitted,

V. R. Covell, Chairman.

The canvass of ballots cast in the annual election was reported by the tellers, Messrs. J. A. Ferguson, H. F. Layton and A. W. Patton as follows:

Walther Riddle, for President	214
S. P. Grace for Vice-President	214
A. E. Frost for Treasurer	214
Samuel E. Duff for Director	213
A. Stucki for Director	213

The above named gentlemen were declared elected.

The President-elect greeted the Society in the following address:

Gentlemen of the Society: I thank you very much for the honor which you have given to me in electing me President of the Engineers' Society of Western Pennsylvania. The reports show that during this year we have gone ahead. This is due not entirely to Mr. Morse or to the Board of Direction, but it is due to the Society as a whole. We have not been 960 separate feathers in a pillow, but we have all been bound together by a good piece of ticking, which is the Engineers' Society, and everything we have done we have done as a unit, and in that way we have had a momentum that has carried us ahead.

I do not believe you appreciate what it means to me to be elected President of this Society. I did not feel, when the question first came to me, that I had the necessary qualifications and the time to give to it, that my predecessors have had, but I did not feel that any man in this Society was big enough to refuse the office as President, if tendered to him. And I want to feel this year that you will help me out, and if you do, we can not help but go ahead and have another successful year. I thank you very much, gentlemen.

No further business coming before the Society the retiring President, Mr. E. K. Morse, addressed the Society on "Personal Experiences and Mistakes in Masonry Construction in the Pittsburgh District."

The meeting adjourned at 10:20 P. M.

Elmer K. Hiles, Secretary.

STRUCTURAL SECTION.

The Annual Meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 3 January, 1911, at 8:05 P. M., Chairman V. R. Covell presiding, 64 members and visitors being present.

The minutes of the last Annual Meeting, held 4 January, 1910, were read and approved.

The Nominating Committee, composed of J. A. McEwen, Chairman; W. M. Judd and W. A. Weldin, reported the following nominations:

Chairman: R. B. Woodworth.

Vice-Chairman: T. J. Wilkerson.

Directors: Edward Godfrey, C. G. Schade, H. F. Layton.

No other nominations being made the Secretary was instructed to cast the ballot for the gentlemen nominated as above who were declared duly elected.

The retiring Chairman addressed the Section in the following remarks:

"The work of the year has been characterized by hearty cooperation on the part of the Executive Committee and the members of the Structural Section, and I desire to express my appreciation publicly at this time. Any success which has attended the work of the year is due to this spirit of cooperation.

In accordance with the amended By-Laws, the programs of the Section for the year have been arranged by the Publication Committee of the Society, of which committee your chairman is a member by virtue of his office. This has resulted in perfect harmony, with no difficulty in securing desirable papers or topical discussions for the Section. Following the last annual meeting, your Executive Committee suggested a general plan for the programs of the year. This was adopted by the Publication Committee and has been adhered to as far as practicable. At the March meeting several short papers were presented dealing with "Present Day Needs in Structural Materials." These papers called attention to some of the unsolved problems which the engineer must meet and master. With one exception, occasioned by the postponement of a paper, this program has been carried through and three of the topics then outlined still remain for future treatment. The interest manifested in the meetings and the character of the papers and discussions seem to indicate a continued demand for the Structural Section.

As the Engineer looks backward over the year 1910, he sees much of more than passing interest in the structural line. In completed buildings, there are two that stand out prominently, The Soldiers Memorial, in Schenley Farms, is interesting in general, but the struc-

tural details, with the Banquet Hall Floor, the clerestory walls, and the roof carried on four double columns and four, eighty-six foot riveted trusses, give added interest, while the Henry W. Oliver Building, in which we meet tonight, is the largest building in Pittsburgh. The building of the Pittsburgh Athletic Association, also on the Schenley Farms, and now under construction, is unusual in having a structural steel, tile-lined swimming-pool on the third floor.

During the year, the first large reinforced concrete arch bridge in the vicinity has been completed by the City of Pittsburgh. This is located on the line of Meadow Street and spans a ravine with a main arch of 210 feet. Of bridge work now under construction, mention should be made of the Ohio River cantilever at Sewickley. This is being built by Allegheny County and has a channel span of 750 feet. The work of rebuilding the piers under the Twenty-Second Street Bridge over the Monongahela River, by the City of Pittsburgh. presented some difficult and interesting problems and will not be completed for some months.

The year 1910 was noticeable in highway construction because of the introduction of paving brick for a wearing surface in an attempt to reduce the excessive maintenance cost that arises with Macadam surfacing.

The year 1911 opens with several engineering projects, of vital importance, under consideration. The proposed new bridge across the Allegheny River at the site of old Union Bridge; the possibility that one or more of the existing Allegheny River bridges will be raised; the construction of a tunnel through the hill south of the Monongahela River, and the ever present rapid transit problem within the business district of the city, present interesting features for future discussion."

Mr. Morris Knowles was requested to escort the Chairman-elect Mr. R. B. Woodworth, to the chair, who said:

"Gentlemen of the Structural Section, I certainly appreciate the honor you have conferred upon me, and I hope very much that the year that is before us will be more successful, if anything, than the year that is behind. It will be very hard for us to do that, because the past year I think, has been a very successful one. I hope that we will have in the year before us the cooperation of every member of the Section and that you will feel free to make any suggestion that you may have to offer."

There being no further business the Annual Meeting adjourned at 8:19 P. M.

The regular bi-monthly meeting was called to order at 8:20 P. M. by Chairman Woodworth.

The minutes of the last meeting, held 1 November, 1910, were read and approved.

No further business coming before the Section the paper of the

evening on "Fireproofing Construction" was read by Mr. Emile G. Perrot, of Ballinger & Perrot, Architects and Engineers of Philadelphia.

The ensuing discussion was participated in by Messrs. W. A. Welding, S. E. Duff, J. A. Ferguson, V. R. Covell, Albert F. Link, R. B. Woodworth, Stephen L. Goodale, E. W. Barthberger and Emile G. Perrot.

The meeting adjourned at 10:13.

ELMER K. HILES, Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Friday, 13 January, 1911, at 5:00 P. M., President Morse presiding, Messrs. Craver, Whited, Frost, Raymer, Handy, Covell and the Secretary being present.

The minutes of the last regular meeting held 9 December, were read and approved.

Applications were received from the following gentlemen and their names ordered published to the Society:

ACTIVE

Tileston Chickering,	F. F. McIntosh,
Samuel D. Foster,	William J. Pertz,
John H. Fox,	Charles H. Vaughan.

The Secretary announced the death of Rees James, December 30, 1910, who joined Society in March, 1899.

Mr. James O. Handy, Chairman of the Medal Committee, composed of Messrs. J. N. Chester, A. R. Raymer and himself, reported that in the opinion of the Committee, no medal should be awarded this year under the existing rules governing medal awards. Mr. Handy recommended that the rule limiting the award of medals for papers presented at meetings of the General Society only, be broadened to include meetings of the Sections of the Society. Mr. H. W. Craver moved that this action be taken, which was carried.

President Morse addressed the Board, congratulating the members on the success they had brought to the Society during the past year, and expressed his warm appreciation of the cordial support which had been extended to him, felicitating the individual members on the happy unity which had characterized their work as a Board.

Mr. A. R. Raymer responded on behalf of the Board, expressing their pleasure in having had opportunity of serving on the Board under such progressive and efficient leadership as marked Mr. Morse's term of office and assured Mr. Morse of the high esteem and warm regard in which he is held by every member of the Board.

The meeting adjourned at 6:00 P. M.

ELMER K. HILES, Secretary.

SPECIAL MEETING.

A special meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Carnegie Institute, February 9th, 1911, at 8:25 P. M., President Riddle presiding, 340 members and visitors being present.

The minutes of the last regular meeting held December 20th, 1910, were read and approved.

No further business coming before the Society the paper of the evening on "Pittsburgh's Transit Problem—Its Broader Technical Aspects" was presented by Bion J. Arnold. The ensuing discussion was participated in by Mayor Magee, George S. Davison, W. E. Reed and B. J. Arnold.

The meeting adjourned at 11:25 P. M.

Elmer K. Hiles,
Secretary.

REGULAR MONTHLY MEETING.

The 308th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Tuesday evening, 21st February, 1911, at 8:15 P. M.; President Riddle presiding, 160 members and visitors being present.

The minutes of the last regular meeting were read and approved.

The Board of Direction reported the election of six and the reinstatement of one Active Member, and the receipt of four applications for Active membership at the meeting of 10th February.

No further business coming before the Society the lecture of the evening on "The Revelations of the Photographic Telescope" was presented by Dr. John A. Brashear. A large number of exceptionally beautiful lantern slides were shown.

The meeting adjourned at 10:00 P. M.

Elmer K. Hiles,
Secretary.

MECHANICAL SECTION.

The Annual Meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, February 7th, 1911, at 8:30 P. M., Chairman Stucki presiding, 46 members and visitors being present.

The minutes of the last Annual Meeting were read and approved.

The report of the nominating committee was presented as follows:

Chairman, Alex. L. Hoerr
Vice Chairman, Edw. V. Wurts
Directors, Edw. D. Leland, Oscar L. Gerwig, H. C. Cronemeyer

On motion the Secretary was requested to cast a unanimous ballot for the gentlemen nominated who were thereupon declared elected.

The Chairman-elect then took the chair and the minutes of the last regular meeting were read and approved.

A brief address was made by Calvin W. Rice, Secretary of the American Society of Mechanical Engineers, who announced that the Spring Meeting of that Society is to be held in Pittsburgh, May 30th to June 2nd, inclusive, of this year. He concluded his remarks by urging closer relations between the National Society and the Engineers' Society of Western Pennsylvania.

The address of the Retiring Chairman on "Achievements in Railroading" was presented by Mr. Stucki.

The ensuing discussion was participated in by Messrs. McCune, McNulty, Hokanson, Gearhart, Danforth, Whitman, and Stucki.

The meeting adjourned at 10:00 P. M.

Elmer K. Hiles,
Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Friday, 10th February, 1911, at 4:55 P. M., President Riddle presiding, Messrs. Morse, Handy, Raymer, Frost, Grace, Whited, Duff, Woodworth and the Secretary being present.

The Minutes of the Special Meeting held 28th December, 1910, and of the regular meeting held 13th January, 1911, were read and approved.

The applications of the following gentlemen having been regularly

published to the Society pursuant to the action of the Board on 13th January they were duly elected to membership:

ACTIVE

Tileston Chickering	F. F. McIntosh
Samuel D. Foster	William J. Pertz
John Herbert Fox	Charles H. Vaughan

A request for reinstatement was received from Karl A. Mullenhoff, Rheinland, Germany, who joined the Society December, 1905, and resigned February, 1908. His request was granted and name ordered placed on the Society Rolls.

Applications were received from the following gentlemen and their names ordered published to the Society:

ACTIVE

Thomas W. Ellis Albert B. Holmes
Harry C. Schmucker

The Secretary announced the death of H. B. Errett, who died on the 29th November, 1910, having joined the Society in April, 1910, and H. E. Ashley, who died on the 6th of February, 1911, having joined the Society in March, 1903.

The report of the Secretary, showing the financial condition of the Society at close of business 31st January, 1911, having been previously audited by the Finance Committee, was approved and bills ordered paid.

Elmer K. Hiles was re-elected Secretary of the Society for the ensuing year.

The matter of the purchase of additional chairs for the Auditorium was introduced, and the House Committee was authorized to purchase thirty new chairs of the same style as those last purchased.

The Secretary reported to the Board that the American Society of Mechanical Engineers have arranged to hold their Spring meeting in Pittsburgh, May 30th to June 2nd, 1911, inclusive. The Board authorized the Secretary to extend to the Local Committee the use of the Society Rooms in connection with their work.

Mr. Morse, who was appointed as a special committee of one to investigate the question of securing permanent quarters for the Society, reported progress. He was requested to continue his work, and was reappointed by the Board. The Board ordered the reappointment of the special committee on Buildings, consisting of George S. Davison, Chairman; John A. Brashear; Thomas H. Johnson; Emil

Swensson and William G. Wilkins. Mr. Morse was requested to consult from time to time with this Committee.

President Riddle introduced the matter of program for professional papers to be presented before the society during the ensuing year, desiring the members of the Board to express opinions on the matter. President Riddle recommended that special attention be given to the matter of securing papers on steel works engineering and metallurgical subjects, as well as some papers on the glass and coal trade industries. After discussion this general policy of program was recommended to the Publication Committee, special stress being laid on the matter of papers relating to steel works and metallurgical subjects.

The meeting adjourned at 6:25 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Friday, 10th March, 1911, at 5:00 P. M., President Riddle presiding, Messrs. Handy, Morse, Raymer, Whited, Duff, Stucki and the Secretary being present.

The minutes of the last regular meeting held 10th February were read and approved.

The applications of the following gentlemen having been regularly published to the Society pursuant to the action of the Board on the 10th February they were duly elected to membership:

ACTIVE

Ellis, Thomas William
Holmes, Albert Bourne
Schmucker, Harry Church
Smith, Carl David.

A request for reinstatement was received from E. E. Rushton, Pittsburgh, Penna., who joined the Society January, 1905, and resigned April, 1906. His request was granted and name ordered placed on the Society Rolls.

Applications were received from the following gentlemen and their names ordered published to the Society:

ACTIVE

Franz, William Elmer
Lewis, John
Kirkland, Elmore Fitch
McGee, Frank Raymond
Pryde, David

JUNIOR

Bray, James M.
Johnson, Carl J.

ASSOCIATE

Booth, James

The report of the Secretary, showing the financial condition of the Society at the close of business 28th February, 1911, having been previously audited by the Finance Committee, was approved and bills ordered paid.

After some discussion on the question of ways and means for providing a permanent home for the Society, the Secretary was requested to call a joint meeting of the Board and the Building Committee at as early a date as would meet the convenience of Dr. Brashear and the other members of the Building Committee.

The meeting adjourned at 5:50 P. M.

Elmer K. Hiles,
Secretary.

BOARD OF DIRECTION

Special Meeting

A Special Meeting of the Board of Direction, attended by the members of the Building Committee, was held in the Society rooms, Oliver Building, Pittsburgh, Friday, 17th March, 1911, at 1:45 P. M., President Riddle presiding, Messrs. Handy, Taylor, Morse, Duff, Chester, Lyons, Whited, Stucki and the Secretary of the Board of Direction, and Messrs. Davison, Brashear, Johnson, Wilkins and Swensson of the Building Committee being present.

President Riddle announced that the meeting was called to consider the matter of a permanent home for the Society and called on Mr. Morse who referred to the matters brought up at the meeting of the Board on December 28, 1910, when he was requested to examine into the matter. He referred to having sent the Secretary to Philadelphia to look into the possibilities of carrying on a work in Pittsburgh similar to that done by the Commercial Museum of Philadelphia and read his correspondence with Mayor Magee relative to the possibilities of securing a site on property owned by the City.

He also reported a consultation he had with Mr. Davison, Chairman of the Building Committee, relative to the matter of interesting some wealthy men in this matter.

President Riddle called on Mr. Davison who reviewed some of the previous experiences of the Society relative to the matter of providing permanent quarters for it and stated, further, that he believed that the Society should always provide its own home and should plan for the future with this in view.

After a general discussion during which Mr. Taylor suggested that a contributing membership in the Society might be established in order to fill the requirements for additional funds for special uses, such as providing for the Entertainment Committee, etc., as outlined by Mr. Morse.

Mr. Davison moved that a committee of three be appointed by President Riddle to work out a plan for a contributing membership, or other plan for increasing the revenues of the Society to be used for special purposes as might be indicated by the Board of Direction from time to time, and that this plan be presented to the Board of Direction for their consideration and action. This motion was seconded by Mr. Swensson and carried.

The joint meeting then adjourned and the Board of Direction went into executive session.

President Riddle stated that Mr. Covell, Deputy County Engr., had taken up with the Secretary a request made by Mr. G. W. McNees, Chairman of the Topographic and Geologic Survey Commission of

Pennsylvania, that action be taken endorsing that item of the Appropriation Bill before the State Legislature providing funds for carrying on the work of this survey.

President Riddle stated, further, that he had requested the Secretary to make inquiries regarding the work being carried on by this commission and a letter was read from Mr. H. J. Painter, of Kittanning, in response to an inquiry made by the Secretary.

Mr. Morse, and other members of the Board, made favorable comments on this work which is being carried on by the United States Geographical Survey under a plan by which the United States Government defrays one-half the expense of the surveys and the State Government provides for the other half.

After discussion the Secretary was requested to prepare letters to be signed by President Riddle addressed to the local members of the Legislature and to the members of the Senate and House Appropriations Committees, endorsing that item in the Appropriation Bill to provide funds for furthering the topographic survey of the State.

The meeting adjourned at 3:15 P. M.

ELMER K. HILES,
Secretary.

REGULAR MONTHLY MEETING

The 309th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 21 March, 1911, at 8:10 P. M., President Riddle presiding, 96 members and visitors being present.

The minutes of the last regular meeting, held 21 February, was read and approved.

The Board of Direction reported the election of four, and the reinstatement of one Active member; the receipt of five applications for Active, two for Junior and one for Associate membership.

No further business coming before the Society the papers of the evening, the "Efficiency of Rope Drives," by Prof. W. Trinks, of the Carnegie Technical Schools, and "Typical Rope Drives for Rolling Mills," by A. A. Neave, of the Mesta Machine Company, was read by Prof. Trinks.

The ensuing discussion was participated in by Messrs. Flint, Rose and Trinks.

After the close of the discussion, President Riddle addressed the Society regarding the work of the Topographical and Geological Survey Commission of Pennsylvania, as follows:

"There is before the State of Pennsylvania a matter interesting to engineers, the topographical survey of the state. This work was

undertaken some years ago by the U. S. Government in connection with our state government. The work has not been completed. The question came up before the Board of Direction at a special meeting. There is a Bill before the Legislature to appropriate money to complete it, and Mr. G. W. McNees, who is Chairman of the State Commission, is here and we would like very much to hear from him."

Mr. G. W. McNees then addressed the Society.

The meeting adjourned at 10:12 P. M.

ELMER K. HILES,
Secretary.

STRUCTURAL SECTION

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 7 March, 1911, at 8:10 P. M.; Chairman R. B. Woodworth presiding, 106 members and visitors being present.

The minutes of the last meeting held 3 January, 1911, were read and approved.

No further business coming before the Section the paper of the evening, on "The Manufacture and Properties of Iron and Steel," was read by Hugh P. Tiemann, Metallurgist with Carnegie Steel Company.

The ensuing discussion was participated in by Messrs. Gilg, Baker and Woodworth.

The meeting adjourned at 10:00 P. M.

ELMER K. HILES,
Secretary.

REGULAR MONTHLY MEETING

The 310th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 18 April 1911, at 8:15 P. M., President Riddle presiding, 137 members and visitors being present.

The minutes of the last regular meeting held 21 March were read and approved.

The Board of Direction reported the election of five Active members, one Associate, and two Juniors, and the receipt of 13 applications for Active membership and one Associate and five Junior applications.

No further business coming before the Society the paper of the evening: "The Electrometallurgical Revolution in the Iron and Steel Industry of Norway and Sweden," was read by Dr. Joseph W. Richards, Secretary of the American Electrochemical Society and Prof. of Metallurgy, Lehigh University.

The ensuing discussion was participated in by Messrs. Riddle, Bole, Vogt and Dr. Richards.

The meeting adjourned at 10:15 P. M.

ELMER K. HILES,
Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday 4 April, 1911, at 8:20 P. M., 105 members and visitors being present.

The minutes of the last regular meeting were read and approved.

No further business coming before the Section, the paper of the evening, "Mechanical and Hydraulic Presses," was presented by Frank I. Ellis, Chief Engineer of the United Engineering & Foundry Company.

The ensuing discussion was participated in by Messrs. Flanagan, Iversen, Hutchinson, Hiles, Hoerr, Smitmans, Landes, Cole, Eden and Ellis.

The meeting adjourned at 10:10 P. M.

ELMER K. HILES, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Friday, 7 April, 1911, at 5:00 P. M.; Vice President Handy presiding, Messrs. Raymer, Whited, Duff, Frost, Stucki, Woodworth and the Secretary being present.

The minutes of the last regular meeting held, 10 March, and the special meeting held 17 March, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society, pursuant to the action of the Board on the 10th of March, were duly elected to membership:

ACTIVE

Franz, William Elmer
Kirtland, Elmore Fitch
Lewis, John
McGee, Frank R.
Pryde, David

ASSOCIATE

Booth, James

JUNIOR

Bray, James M.
Johnson, Carl J.

Applications were received from the following gentlemen, and their names ordered published to the Society:

ACTIVE

Henry, John B.
Lowrie, William L.
Mesnard, Howard
Osler, J. T.
Partington, J. A.
Remmen, J.
Holstein, Shoffer N.
Malstrom, Uno
Nibecker, Karl
Ow, J. W. W.
Ross, John B.
Smith, Russell
Steele, L. C.

ASSOCIATE

Rose, Thomas L.

JUNIOR

Banbrook, Hermann
Harrison, Joseph H.
McKee, Edwin B.
Wisner, John L.
Wiskeman, Elmer

The report of the Secretary showing the financial condition of the Society at the close of business, 31 March, 1911, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The Secretary presented a letter received from the Pennsylvania State College, requesting that the Society appoint three delegates to the body of electors who are to elect the members of the Board of Trustees for the College for the ensuing year. The Secretary was requested to ascertain what members of the Society who are graduates of the State College, expect to attend the Commencement exercises with the idea of having them serve as delegates from this Society.

The meeting adjourned at 5:35 P. M.

ELMER K. HILES, Secretary.

REGULAR MONTHLY MEETING

The 311th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 16 May, 1911, at 8:20 o'clock, Mr. A. R. Raymer presiding, in the absence of the President, 52 members and visitors being present.

The minutes of the last regular meeting held 18 April were read and approved.

The Board of Direction reported the election of thirteen Active members, one Associate and five Juniors and the reinstatement of two Active members, also the receipt of twelve applications for Active membership and five Junior and one Junior-Student applications.

No further business coming before the Society the address of the evening on the "National Bureau of Standards and Its Work" was made by Dr. S. W. Stratton, Director of the Bureau.

The ensuing discussion was participated in by Messrs. Banks, Wilkerson, and Stratton.

The meeting adjourned at 9:50 P. M.

Elmer K. Hiles,
Secretary.

STRUCTURAL SECTION

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 2nd May, 1911, Chairman R. B. Woodworth presiding, 57 members and visitors being present.

The minutes of the last meeting, held 7th March, were read and approved.

No further business coming before the Section the paper of the evening "The Deterioration of Macadam Roads and the Probable Cure", was read by Samuel D. Foster, County Road Engineer for Allegheny County.

The ensuing discussion was participated in by Messrs. J. W. Hunter, E. C. Brown, W. G. Wilkins, J. O. Handy, L. P. Blum, W. D. Craven, Jr., C. L. McKenzie and S. D. Foster.

The meeting adjourned at 10:15 P. M.

Elmer K. Hiles,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Friday, 5 May, 1911, at 5:00 P. M., Vice President Grace and President Riddle presiding; Messrs. Raymer, Duff, Stucki and the Secretary being present, as was also Harrison W. Craver.

The minutes of the last regular meeting held 7 April, were read and approved.

The applications of the following gentlemen having been regularly published to the Society pursuant to the action of the Board on the 7th of April, were duly elected to membership:

ACTIVE

Henry, John B.
Lowrie, William S.
Mesnard, Howard W.
Osler, J. T.
Partington, J. A.
Remmen, J.
Holstein, Shoffer N.
Malmstrom, Uno
Nibecker, Karl
Ow, J. W. W.
Ross, John B.
Smith, Russell
Steele, L. C.

ASSOCIATE

Rose, Thomas L.

JUNIORS

Banbrook, Hermann
Harrison, Joseph A.
McKee, Edwin B.
Wisner, John L.
Wiskeman, Elmer

Requests for reinstatement were received from the following gentlemen; and their names ordered placed on the Society rolls:

Baltzell, W. H., joined Dec. 1892; resigned March 1907.
Bissell, David S., joined Jan. 1903; resigned Jan. 1910.

Applications were received from the following gentlemen and their names ordered published to the Society:

ACTIVE

Arensberg, F. L.
Brennan, Walter A.
Eastman, Horace M.
Freund, Jacob De S.
McKenna, W. A.
Tiemann, Hugh P.
Braden, Earl V.
Brown, John T., Jr.
Fouse, John M.
Gasteiger, J. A.
Miller, Karl E.
Weinthal, Solon M.

JUNIOR

Baird, Frank L.
Dowling, Eugene
Davison, Allen S.
Hill, G. Max
Wood, S. C.

JUNIOR-STUDENT

Koenig, Simon William

The report of the Secretary showing the financial condition of the Society at the close of business April 30, 1911, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The Secretary reported that Mr. W. E. Snyder, a member of the Society, proposed attending the commencement exercises at State College, and the Secretary was requested to advise Mr. Snyder of his appointment as delegate to the Board of Electors for 1911, who are to elect the members of the Board of Trustees for the college.

Mr. Handy, Chairman of the Entertainment Committee, reported that arrangements were under way for a Smoker to be held on Friday evening, 2 June, for the entertainment of the members of the American Society of Mechanical Engineers attending the Spring meeting of that Society in Pittsburgh.

Mr. Handy further reported that the Entertainment Committee was considering the advisability of arranging for a two-day trip to Cambridge Springs as an outing for the Society in June; this met with the very cordial approval of the Board.

The meeting adjourned at 6:15 P. M.

Elmer K. Hiles,
Secretary.

REGULAR MONTHLY MEETING

The 312th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 20 June, 1911, at 8:30 P. M. Vice-President Handy presiding, 61 members and visitors being present.

The minutes of the last regular meeting held 16 May were read and approved.

The Board of Direction reported the election of twelve Active members, five Juniors and one Junior-Student and the receipt of six applications for Active membership and two Junior-Student applications.

No further business coming before the Society the paper of the evening by E. E. Lanpher, Division Engineer, Bureau of Water, and L. B. Smith, Assistant Engineer, Bureau of Water, on "Electrolysis of Water System Underground Structures in Pittsburgh" was read by Mr. Lanpher.

The ensuing discussion was participated in by Messrs. Burton McCollum, Assistant Physicist, Bureau of Standards, James O. Handy, F. Uhlenhaut, Jr., W. Edgar Reed, W. E. Mott, F. N. Speller, J. P. Fox, L. B. Smith and E. E. Lanpher.

The meeting adjourned at 10:25 P. M.

ELMER K. HILES,
Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, June 6th, 1911 at 8:30 P. M.; Chairman A. L. Hoerr presiding, 58 members and visitors being present.

The minutes of the last meeting of the Section, held April 4th were read and approved.

No further business coming before the Section the paper of the evening "The Operation of Boiler Plants of Industrial Works" was presented by John A. Hunter, Mechanical Engineer, American Sheet and Tin Plate Company.

The ensuing discussion was participated in by Messrs. Vance, W. E. Snyder, Benner, Cronemeyer, Bergwin, Shook, Albree, Geo. T. Snyder, Stucki, Low, Leahy, Smith and Hunter.

The meeting adjourned at 10:10 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Monday, 12 June, 1911, at 4:45 P. M., President Riddle presiding, and Messrs. Lyons, Taylor, Stucki, Duff, Handy, Raymer, Grace, Whited and the Secretary being present.

The minutes of the last regular meeting, held 5 May, 1911, were read and approved.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board of the 5th of May, 1911, were duly elected to membership:

ACTIVE

Arensburg, F. L.
Brennan, Walter A.
Eastman, Horace M.
Freund, Jacob DeS.
McKenna, W. A.
Tieman, Hugh P.
Braden, Earle V.
Brown, John T., Jr.
Fouse, John M.
Gasteiger, J. A.
Miller, Karl E.
Weinthal, Solon M.

JUNIOR

Baird, Frank L.
Dowling, Eugene
Davison, Allen S.
Hill, G. Max

JUNIOR-STUDENT

Koenig, Simon William

Applications were received from the following gentlemen and their names ordered published to the Society:

ACTIVE

Jayme, J. Phillip
Newton, Ralph W.
Ringle, Robert F.
Leet, Clifford S.
Packard, G. F.,
Walker, Hay

JUNIOR-STUDENT

Koerbel, Frederick H.
Stearns, Karl Thompson

The Secretary announced the death of F. S. Jackman, who died 6 May, 1911; having joined the Society in March 1899.

The report of the Secretary, showing the financial condition of the Society at close of business 31 May, 1911, having been previously audited by the Finance Committee was approved and bill ordered paid.

The Secretary read a letter from Mr. Ludwig Gutmann from St. Louis, requesting this Society to pass a resolution requesting President Taft to urge Congress to establish a permanent commission of department, for the supervision of patents. A letter was also read which the Secretary had addressed to Mr. Gutmann, requesting in-

formation as to what Society or organization of engineers he was writing in behalf of. Action on Mr. Gutmann's request was deferred until further information was received from him in answer to the Secretary's letter of inquiry.

Mr. Handy, Chairman of the Entertainment Committee, reported verbally that the proposed Outing to Cambridge Springs had been called off after consultation with President Riddle, owing to the small number of replies received from members indicating that they would participate in the excursion.

Mr. Handy further reported that the expenses in connection with the Smoker tendered the visiting members of the American Socity of Mechanical Engineers, at the Union Club, Friday, 2 June, were within the sum appropriated by the Board. The general success of this Smoker was commented on and many favorable things said regarding the manner in which the Smoker was conducted and an expression of appreciation, and thanks which was concurred in by the entire Board, was extended to the Entertainment Committee for their splendid work in arranging the details of the Smoker given in honor of the American Society of Mechanical Engineers, Friday evening, 2 June, which was considered complete in its appointments in every particular and one of the most successful affairs the Society ever held.

The matter of Mr. W. G. Wilkins' appointment, as a member of the new Pittsburgh Council, by Governor Tener, was introduced, and the Secretary requested to write a letter to Governor Tener, congratulating him upon the personnel of the newly appointed Council for the City of Pittsburgh, especially upon the appointment of Mr. W. G. Wilkins, a Past President of this Society.

Mr. S. A. Taylor referred to the matter of the $5 subscription price for the Proceedings to Junior-Student members of the Society. It was explained that the committee of which Mr. H. W. Craver is Chairman had in mind that this matter would be taken care of by an appropriation to be passed by the Board, providing funds to make up the subscriptions of Junior-Students. The Secretary was asked to request Mr. Craver to make such a recommendation to the Board in order that our records might be complete.

Adjourned at 5:20 P. M.

Elmer K. Hiles,
Secretary.

REGULAR MONTHLY MEETING

The 313th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, September 19th, 1911, at 8:30 P. M., President Riddle presiding, 69 members and visitors being present.

The minutes of the last regular meeting held June 20th were read and approved.

The Board of Direction reported the election of six Active members, and one Junior, and the receipt of 10 applications for Active membership and one Junior application.

No further business coming before the Society the paper of the evening on "Relative Advantages of Group and Individual Motor Drives and the Cost of Industrial Electric Power" was read by C. W. Drake.

The ensuing discussion was participated in by Messrs. W. E. Reed, A. Stucki, A. G. Popcke, E. K. Hiles and C. W. Drake.

The meeting adjourned at 10:15 P. M.

ELMER K. HILES,
Secretary.

SPECIAL MEETING

A special meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Wednesday, September 27th, 1911, at 8:50 P. M., President Riddle presiding, 285 members and visitors being present.

Charles Y. Knight of Coventry, England, delivered an address on "Gas Motors for Automobiles with Special Reference to Valve Gears."

The Ensuing discussion was participated in by Messrs. Cadwallader Evans, Jr., S. P. Grace, and two or three non-members of the Society.

The meeting adjourned at 10:55 P. M.

ELMER K. HILES,
Secretary.

STRUCTURAL SECTION

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, September 5th, 1911, at 8:10 P. M.; Chairman R. B. Woodwarth presiding, 50 members and visitors being present.

The minutes of the last meeting held May 2nd, were read and approved.

No further business coming before the Section, the discussion of the evening on "Non Metallic Roofing Material" was opened by W. S. Babcock, Waterproofing Engineer, Barrett Mfg. Company, New York; with a paper on "Built Up Roofs". The following papers were then presented:

"Concrete Roofs", by W. M. Kinney, Inspection Engineer, Universal Portland Cement Company, Pittsburgh.

"Asbestos Roofing Materials", by Geo. R. Folds, Manager, H. W. Johns-Manville Company, Pittsburgh.

"Cement Tile Roofing", by J. de S. Freund, Secretary & Treasurer, American Cement Tile Mfg. Co., Pittsburgh.

The ensuing discussion was participated in by Messrs. Samuel E. Duff, W. M. Judd, James O. Handy, W. S. Babcock, G. R. Folds, J. de S. Freund, L. P. Blum, and W. M. Kinney.

The meeting adjourned at 10:15 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Friday, July 7th, 1911, at 4:50 P. M., President Riddle presiding, Messrs, Handy, Grace, Whited, Stucki, Frost and the Secretary being present.

The minutes of the last regular meeting, held June 12th, were read and approved.

The applications of the following gentlemen having been regularly published to the Society pursuant to the action of the Board on June 12th, 1911, were duly elected to membership:

ACTIVE

Jayne, J. Phillip,
Newton, Ralph W.,
Ringle, Robert F.,
Leet, Clifford S.,
Packard, G. F.,
Walker, Hay.

JUNIOR-STUDENT

Koerbel, Frederick H.,
Stearns, Karl Thompson.

Applications were received from the following gentlemen and their names ordered published to the Society:

ACTIVE

Benner, Jacob W.,
Horton, E. J.,
Neave, Andrew A.,
Grant, John M.,
Mick, Bert A.,
Willock, Sylvester R.

JUNIOR

MacLeod, James T.

The report of the Secretary, showing the financial condition of the Society at the close of business June 30th, 1911, having been previously audited by the Finance Committee was approved and bills ordered paid.

The Secretary presented the following recommendation from Harrison W. Craver, Chairman of the special committee on Second Class Classification: "Resolved: That the Secretary of the Society be authorized to set aside annually from the General Fund of the Society, $2.00 for each Student-Junior member of the Society which amount is to be applied on the subscription of Student-Junior members for the Proceedings of the Society." This recommendation being offered in order to bring our records into conformity with the requirements of the Post Office Department. It was moved and seconded that the report of the committee be accepted and the resolution recommended was passed unanimously.

The Secretary reported on behalf of Mr. Reymer, Chairman of the House Committee, who was unable to be present at the meeting, that a number of the cane seated chairs in the auditorium required to be reseated, with the recommendation that the expenditure for these repairs be authorized. The Secretary was authorized to have this work done.

A letter received from the Institution of Mining Engineers of London, in response to a request from exchange of publications made by the Secretary, was read. The Secretary was authorized to make an exchange of publications in accordance with the plan proposed in their letter.

A letter was read from Calvin W. Rice, Secretary of the American Society of Mechanical Engineers, expressing that Society's appreciation of the entertainment provided for them during their Pittsburgh meeting, at the Smoker held in the Union Club on June 2nd.

The meeting adjourned at 5:25 P. M.

Elmer K. Hiles,

Secretary.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Friday, September 8th, 1911, at 5:10 P. M., Vice President Handy presiding, and Messrs. Grace, Morse, Taylor, Lyons, Duff, Whited and the Secretary being present.

The minutes of the last regular meeting, held 7 July, were read and approved.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board on July 7th, 1911, were duly elected to membership:

ACTIVE

Benner, Jacob W.,
Horton, E. J.,
Neave, Andrew A.,
Grant, John M.,
Mick, Bert A.,
Willock, Sylvester R.

JUNIOR

MacLeod, James T.

John H. K. Burgwin was reinstated to Active Membership, having joined in March 1903, and resigned in December 1904.

Applications were received from the following gentlemen and their names ordered published to the Society:

ACTIVE

Adams, Edward S.,
Crea, Thomas C.,
Harshbarger, Elmer D.,
Hurst, N. C.,
Warren, George S.,
Carnes, William K.,
Elverson, Howard W.,
Huntley, Louis G.,
Pinger, G. C.,
Wilcox, Charles L.

JUNIOR

Patterson, Martin Lynn.

The reports of the Secretary, showing the financial condition of the Society at close of business July 31st and August 31st, 1911, having been previously audited by the Finance Committee were approved and bills ordered paid.

The Secretary presented a letter from the President of the Third National Conservation Congress, to be held in Kansas City, September 25th to 27th inclusive, inviting this Society to appoint delegates. After discussion the following delegates were appointed:

Thomas H. Johnson, Chairman, Consulting Engineer, Pennsylvania Lines West, Union Station, Pittsburgh.

R. E. Miller, Asst. Engr. of Bridges, St. L. & S. F. R. R., Frisco Building, Springfield, Mo.

Welch, William M., Chief Engineer, Kansas Natural Gas Company, Independence, Kans.

Mr. S. P. Grace introduced the matter of a proposed reception gotten up by the engineers of Pittsburgh, as a fitting recognition of Mr. Scott's work in Pittsburgh and his high attainments as an engineer. Mr. Grace stated that an informal meeting of a number of engineers of the city, some connected with scientific organizations and others who were not, had been held to consider the advisability of holding such a reception. Mr. Grace recommended that this Society might very properly take the lead in such a movement as being the the oldest engineering organization in the city, and further, in view of the fact that Mr. Scott is a Past President of the Society. After consideration, Mr. Grace and the Entertainment Committee were authorized to proceed with plans looking toward a reception, or such other function as might be deemed most expedient.

Mr. S. A. Taylor, Vice President of the American Mining Congress, introduced the matter of appointing delegates to the Fourteenth Annual session of that organization, to be held in Chicago, 24 October to 28th inclusive. After discussing the matter of appointing delegates, it was placed in the hands of the President, Mr. Taylor and the Secretary, who selected the following delegates:

J. G. Hempstead, Works Manager, Continental Bolt & Iron Works, Chicago.

H. B. Douglas, Works Manager, Standard Steel Car Co., Hammond, Ind.

The meeting adjourned at 6:15 P. M.

ELMER K. HILES,

Secretary.

REGULAR MONTHLY MEETING

The 314th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, October 17th, 1911, at 8:15 P. M., President Riddle presiding, 92 members and visitors being present.

The minutes of the last regular meeting held September 19th, were read and approved.

The Board of Direction reported the election of ten Active members, and one Junior, and the receipt of three applications to Active membership, one Associate and three Junior applications.

President Riddle announced the appointment of the 1911 Nominating Committee as follows:

Morris Knowles, Chairman,

Samuel E. Duff,	E. H. Haslam,
Samuel B. Ely,	W. E. Snyder.

No further business coming before the Society the paper of the evening on "Acids in the Monongahela River", was read by Col. Thomas P. Roberts of the U. S. Engineer Office, Pittsburgh.

The ensuing discussion was participated in by Messrs. J. R. Campbell, Chief Chemist, H. C. Frick Coke Company, Scottdale; J. O. Handy, W. E. Snyder, (whose contributed discussion was read by the Secretary); R. B. Dole, Assistant Chemist, Water Resources Branch, U. S. Geological Survey, Washington, D. C.; B. A. Ludgate, Assistant Engineer, P. & L. E. R. R.; Farley Gannett, Chief Engineer, Water Supply Commission of Penna., Harrisburg; J. N. Chester, Morris Knowles, Dr. E. G. Matson, Bureau of Health; and E. C. Trax, Chief Operator, Municipal Filtration Plant, McKeesport, Pa.

The Meeting adjourned at 10:55 P. M.

Elmer K. Hiles,
Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania, was held in the society rooms, Oliver Building, Pittsburgh, Tuesday, October 3rd, 1911, at 8:25 P. M. The meeting was called to order by Vice-President Handy, 92 members and visitors being present.

The minutes of the last meeting held June 6th, were read and approved.

No further business coming before the Section the paper of the evening, "The Smokeless Combustion of Bituminous Coal in the Pitts-

burgh District", was presented by Mirabeau Sims, Vice-President, Steam Equipment Mfg. Co.

The ensuing discussion was participated in by Messrs. John A. Hunter, D. F. Crawford, D. P. Morrison, W. E. Snyder, W. G. Wilkins, S. B. Flagg, I. W. Frank, H. C. Porter, C. E. Augustine and Mirabeau Sims.

The meeting adjourned at 10:27 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Friday, October 6th, 1911, at 4:55 P. M., Vice-President Handy presiding, Messrs. Chester, Morse, Whited, Raymer, Duff and the Secretary being present.

The minutes of the last regular meeting, held 8 September, were read and approved.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board on September 8th, were duly elected to membership:

ACTIVE

Adams, Edward S.
Crea, Thomas C.
Harshbarger, E. D.
Hurst, N. C.
Warren, G. S.
Carnes, William K.
Elverson, Howard W.
Huntley, Louis G.
Pinger, G. C.
Wilcox, Charles L.

JUNIOR

Patterson, Martin Lynn.

Applications were received from the following gentlemen and their mames ordered published to the Society:

ACTIVE

Gerber, Christian G.
Schreiber, J. W.
Town, Frederick E.

ASSOCIATE

Schroth, Albert J.

JUNIOR

Peters, Frank Grant
Wallace, William S.
White, Audley D.

The report of the Secretary showing the financial condition of the Society at close of business September 30th, 1911, having been pre-

viously audited by the Finance Committee, was approved and bills ordered paid.

A letter was read from the Secretary of the Automobile Club of Pittsburgh, transmitting the thanks of the Board of Governors of that organization for the invitation extended to them to hear Mr. Charles Y. Knight's paper on "Gas Motors for Automobiles with Special Reference to Valve Gears."

The Secretary read a letter received from the Post Office Department advising that upon the showing made of bona fide subscriptions to the Proceediings that our publication was to be continued as Second Class matter.

The Secretary read a letter from H. M. Howe, Chairman, and H. F. Porter, Secretary of the Organizing Committee of the Sixth Congress of the International Association for Testing Materials, inviting the Engineers' Society of Western Pennsylvania to send a representative to this Congress to be held in New York City September 3, 1912. After discussion the Secretary was requested to reply to this letter advising that this Society would appoint a representative to attend this Congress, and requesting that our Society be entered on their records as being represented.

The meeting adjourned at 5:30 P. M.

Elmer K. Hiles,
Secretary.

REGULAR MONTHLY MEETING

The 315th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, November 21st, 1911, at 8:15 P. M., Vice-President Handy presiding. 72 members and visitors being present.

The minutes of the last regular meeting held October 17th, were read and approved.

The Board of Direction reported the election of three Active members, one Associate, and three uniors, and the receipt of ten applications for Active membership, and two Junior applications.

The death of J. L. Lewis was announced. Mr. Lewis joined the Society in March 1880, and died November 6, 1911.

The following report of the Nominating Committee was read:

To the Board of Direction. Nov. 2, 1911.
Engineers' Society of Western Penna.,
Oliver Building, Pittsburgh.

Dear Sirs:

Your Nominating Committee beg to submit the following nominations as the unanimous choice of the Committee as candidates for the several offices to be filled:

President,	James O. Handy.
Vice President,	S. A. Taylor, (2 Yrs.)
Treasurer,	A. E. Frost.
Directors,	A. L. Hoerr, W. C. Hawley.

Respectfully submitted,

NOMINATING COMMITTEE:

Morris Knowles, Chairman,
Samuel E. Duff,
Sumner B. Ely,
E. H. Haslam,
W. E. Snyder.

The following report of Wm. M. Welch, who represented the Society at the Third National Conservation Congress, was read:

The Sessions of the 1911 National Conservation Congress at Kansas City on Sept. 25, 26 and 27, were largely attended by delegates from a great many states, cities, civic and scientific bodies, institutions of learning, etc.

The representatives of the governors of the various states, members of conservation commissions of the states and professors of agricultural colleges or departments of state universities probably made up the larger part of the delegates. There were but few delegates from scientific or engineering associations.

The Congress devoted its attention almost exclusively to rural life, great emphasis being laid upon the building up of the soil as against its impoverishment by wasteful farming methods.

There can be no doubt that the work of the Congress along these lines will be invaluable in our agricultural development for reports of this Congress will be sent broadcast over the country in the farmers' journals and magazines which are intended to reach the remotest parts of our rural communities. The general welfare of our rural population was also discussed along many channels, as its churches, schools, farmers' institutes and home life. The direction of the attention of this congress along the lines which it took was undoubtedly due to the influence of its President, Dr. Henry Wallace, a noted agriculturist and editor, and the success of the Congress was also unquestionably due to his wise counsel and firm hand in directing its activity.

There was a noticeable absence of friction or controversy in the discussions, and also of the parties to the controversy of last year, and of representatives of so-called "special interests." This may be due to the trend along agricultural lines which the Congress took rather than to any change of views or sentiment on the part of those persons who made the 1910 Congress notable for its dissension.

The formal addresses presented and previously announced as making up the program of the sessions were necessarily of a more or less general character as they were read before the entire body of delegates and the general public which was admitted to the sessions.

Professional papers or scientific discussions with accurate information along the lines treated would have been very uninteresting before such an audience no matter how valuable they might be to those delegates specially interested in the subjects. As suggested by the delegates of our Society to the 1910 Congress there should be sub-organizations of the Congress or sections such as Engineering, Civic, Educational, Public Health, including Sanitation and Pure Food, Forestry, etc., and the place for such papers is in the meetings of the delegates who have a common interest in such branches of science or learning.

There was one such body or section, the meetings of which were attended as fully as possible by me. This was of the delegates of the State Conservation Commissions and was made up largely of state geologists and professors of agricultural colleges, and the subjects discussed were agricultural and the correlated branches of science.

This body had its inception at the 1910 Congress, but has not yet "found itself," and in the 1911 sessions the delegates from national scientific societies were invited to participate. This meeting occupied the entire second day, beng held simultaneously with the general sessions.

Some carefully prepared papers were presented and these contained facts and figures which must prove valuable to anyone desiring to use them. I believe it is the intention of this section to have those papers published in connection with the proceedings of the Congress, although on this point I am not clear. There were also several informal talks given by the geologists, agriculturists, etc., but as these were impromptu no report of them was made.

I also attended several meetings of the delegates of national scientific societies and participated in a resolution which was presented to the Congress, a copy of which resolution and the societies represented is herewith attached.

The conclusions which I have arrived at as a result of my attendance at the sessions of this Congress follow.

First: That the Congress is rapidly emerging from the formative period and arriving at fixed aims and purposes.

Second: That this Congress was able to accomplish considerable good in the fields covered by the papers and addresses presented.

Third: That the greatest good along the many special lines will be accomplished not in the large general meetings of the Congress but in the smaller meetings of sections or departments where scientific papers may be presented and discussed by those persons specializing in such fields.

Fourth: That the organization of such sections will not be accomplished by the General Congress, but any group of eligible bodies, that wishes to be identified with the conservation movement as carried forward by the Congress must take the initative and proceed with its organization and then ask to be allowed to become identified with the Congress. These sections being recognized by and operating under the authority and jurisdiction of the General Congress will be given publicity and support by that body.

An advisory board to the executive committee was authorized by the Congress which board is to be made up of one representative from each national scientific or civic association having a conservation committee. A meeting of the executive committee of the Congress and the representatives of such societies was held, at which I was able to qualify for our Society as being of national scope and the right to membership on this board was granted to it. If our Society wishes to have such representation it should, to make the matter entirely in accordance with the resolution, proceed to name a conservation committee and also to name its representative for the board.

As engineering is and has always been essentially a profession of conservation, it would seem that the engineering societies of the country should be identified with this national conservation movement and that they should be able to exert a very great influence upon it; and in my judgment they can exert just as great an influence as they wish by directing their efforts to that end.

The engineering profession holds some of the country's greatest citizens and probably the most able to direct such a movement. Who more fitted for the Presidency of the Conservation Congress could there be than Colonel Goethals or Mr. Julian Kennedy, or others of our eminent engineers?

Respectfully submitted,

Oct. 30, 1911. W. M. WELCH, Delegate.

Resolutions adopted at a meeting of delegates representing scientific and technical national associations, members of the Third National Conservation Congress, September 26, 1911.

Recognizing fully the great value of enthusiasm and sentiment in the furtherance of any movement for the public good; and expressing our appreciation of the work of the noble and self-sacrificing men and women who have stirred the people of our country to an understanding of dangers which have resulted, or must inevitably result, from the abuse of our national resources:

We, delegates representing National Scientific and Technical organizations, believe that the constructive stage in the policy of conservation has been reached, and that if this policy is to bring lasting benefits to our people it must be based upon disinterested information and exact truth.

We call attention to the fact that much of the information which we now have concerning our resources, such as that related to the public health, the soils, the forests, the streams and the climate, is still indefinite and in large part not correlated with reference to the various parts of our country.

We, therefore, urge upon all who are concerned with the actual work of conservation, whether in the state or in the nation, that they secure as quickly as possible exact knowledge concerning our various resources and the conditions which affect their development through unprejudiced scientific investigation, and that all constructive conservation policies be based upon such exact information.

EDWARD J. TAYLOR, Chairman,
J. F. NICKERSON, Secretary.

ASSOCIATIONS REPRESENTED

American Association for the Advancement of Science,
American Institute of Electrical Engineers,
American Institute of Chemical Engineers,
American Chemical Society,
American Electrochemical Society,
American Association of Refrigeration,
American Society of Civil Engineers,
American Society of Engineering Draftsmen,
American Society of Refrigerating Engineers,
American Society of Mechanical Engineers,
Engineers' Society of Western Pennsylvania,
American Society of Engineering Education.

Official Program

THIRD NATIONAL CONSERVATION CONGRESS
Convention Hall, Kansas City, Mo.
September 25, 26, 27, 1911

OPENING DAY—SEPTEMBER 25.

Forenoon Session—10 o'clock.

INVOCATION—The Rt. Rev. Thomas F. Lillis, Bishop of the Roman Catholic Diocese of Kansas City.

ADDRESSES OF WELCOME:—On behalf of Kansas City, Hon. Darius A. Brown, Mayor of Kansas City; On behalf of the Commercial and Industrial Organizations of Kansas City, Mr. J. C. Lester, President, Kansas City Commercial Club; On behalf of the State of Missouri, Hon. Herbert S. Hadley, Governor of Missouri.

Response and Address—Dr. Henry Wallace, Des Moines, Iowa, President, Third National Conservation Congress.

Response—Hon. J. B. White, Kansas City, Mo., Chairman, Executive Committee, National Conservation Congress.

ANNOUNCEMENTS.

Afternoon Session—2 o'clock.

INVOCATION—The Rev. Dr. R. M. Kerr, Pastor, First United Presbyterian Church of Kansas City.

Appointment of Committee, Announcements, Etc.

CONFERENCE OF THE STATES.

Presiding Governor, Hon. Herbert S. Hadley, of Missouri.

Addresses by the Governors and other Representatives of the States.

Reports from the State Conservation Commissions and other Organizations Concerned in Conservation.

THE COUNTRY CHILD VS. THE CITY CHILD—Hon. Ben B. Lindsey, Denver, Colo.

Evening Session—8 o'clock.

ADDRESS BY THE PRESIDENT OF THE UNITED STATES.

SECOND DAY—September 26.

Forenoon Session—9:30 o'clock.

INVOCATION—The Rev. Dr. R. E. Hendrix, Kansas City, Bishop of the Methodist Episcopal Church South.

Routine Business, Announcements, Etc.

Reports from the Conservation Committees of National Organizations, and from other Organizations Concerned in Conservation.

ADDRESS—Mr. Charles S. Barrett, Union City, Ga., President, Farmers' Educational and Co-operative Union of America.

SOCIAL LIFE ON THE FARM—Prof. P. G. Holden, Iowa State College, Ames, Iowa, representing the National Grange.

CO-OPERATION—Mr. W. A. Beard, Sacramento, Cal.

THE FARMER AND THE RAILROADS—Mr. Herbert Quick, Madison, Wis., Editor, Farm and Fireside.

Afternoon Session—2 o'clock.

INVOCATION—The Rev. Dr. George Hamilton Combs, Pastor, Independence Boulevard Christian Church.

Routine Business, Announcements, Etc.

Reports from Conservation Committees.

THE LIVE STOCK FARM AND SOIL FERTILITY—Dr. Frederick B. Mumford, Dean, University of Missouri, Columbia, Mo.

THE COUNTRY SCHOOL—Mr. Walter H. Page, New York City, Editor, The World's Work.

THE FARMER'S WIFE—Mrs. Harriet Wallace Ashby, Des Moines, Ia.

Discussion, led by Mrs. J. M. Lewis, Kinsley, Kansas.

Evening Session—8 o'clock.

THE COMMUNITY CLUB—Mrs. Philip N. Moore, St. Louis, Mo., President, General Federation of Women's Clubs.

THE CHURCH IN THE OPEN COUNTRY—Dr. Warren H. Wilson, New York City, Superintendent, Board of Home Missions of the Presbyterian Church.

THE HEALTH OF THE PEOPLE—Dr. Harvey W. Wiley, Washington, D. C., Chief, Bureau of Chemistry, U. S. Department of Agriculture.

THIRD DAY—September 27.

Forenoon Session—9:30 o'clock.

INVOCATION—The Rev. Dr. S. M. Neel, Pastor, Central Presbyterian Church of Kansas City.

Routine Business, Reports of Committees, Announcements, Etc.

HOW GOOD ROADS HELP THE FARMER—Hon. Curtis Hill, Jefferson City, Mo., State Highway Engineer of Missouri.

PRACTICAL FORESTRY IN EUROPE AND AMERICA—Hon. J. B. White, Kansas City, Mo.

WHAT DEMONSTRATION FARMS HAVE DONE FOR THE SOUTH—Dr. Bradford Knapp, Washington, D. C., United States Department of Agriculture.

THE TREND OF THE CONSERVATION MOVEMENT—Dr. W. J. McGee, Bureau of Soils, U. S. Department of Agriculture.

CONSERVATION AND THE PUBLIC DOMAIN—Hon. Walter L. Fisher, Secretary of the Interior.

Afternoon Session—2 o'clock.

Presiding Officer, Mr. F. D. Coburn, Topeka, Kans., Secretary, Kansas Department of Agriculture.

INVOCATION—The Rev. Dr. Donald Duncan Munro, Pastor of the Calvary Baptist Church of Kansas City.

Routine Business, Announcements, Etc.

DAIRYING AND SOIL FERTILITY—Hon. W. D. Hoard, Ft. Atkinson, Wis.

PROPER METHODS OF SOIL CULTIVATION—Prof. A. M. Ten Eyck, Kansas State Agricultural College, Manhattan, Kans.

WORN-OUT SOILS—Prof. Cyril G. Hopkins, University of Illinois, Champaign, Ill.

THE RAPE OF THE SOIL—Mr. A. P. Grout, Winchester, Ill., representing the National Soil Fertility League.

ADDRESS—Dr. H. J. Waters, President, Kansas State Agricultural College, Manhattan, Kans.

ADDRESS—Hon. William Jennings Bryan, Lincoln, Neb.

Reports of Committees.
Adoption of Resolutions.
Election of Officers.
Adjournment.

Mr. W. G. Wilkins, referring to an article in the November 16th issue of the Engineering News, commenting on Bulletin No. 39, issued by the U. S. Office of Public Roads, moved that the President of the Society be authorized to appoint a committee of three to frame resolutions protesting against it, and to forward same to the Secretary of Agriculture.

The motion was duly seconded and carried.

Announcement was made of the Inspection Trip to be made to the Cambria Steel Company's Works at Johnstown on November 25th.

No further business coming before the Society the paper of the evening on "Engineering Requirements in Bituminous Coal Mining," was read by Wm. E. Fohl, Mining Engineer, Pittsburgh.

The ensuing discussion was participated in by F. Z. Schellenberg, W. W. Macfarren, W. G. Wilkins, C. B. Albree, L. P. Blum, W. A. Weldin, Harry J. Lewis, Geo. R. Wood, A. C. Fieldner, Dr. H. C. Porter, G. A. Burrell and Geo. S. Rice, of the Bureau of Mines; E. D. Dreyfus, Westinghouse Machine Co.; Dr. Jos. A. Holmes, Director of the Bureau of Mines; S. A. Taylor, Morris Knowles, G. E. Flanagan, and W. E. Fohl.

The meeting adjourned at 10:45 P. M.

ELMER K. HILES,
Secretary.

STRUCTURAL SECTION

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, November 7th, 1911, at 8:15 P. M., Chairman R. B. Woodworth presiding, 69 members and visitors being present.

The minutes of the last meeting, held September 5th, were read and approved.

The 1912 Nominating Committee was appointed as follows:

W. M. Judd, V. R. Covell,
P. S. Whitman.

No further business coming before the Section, the discussion of the evening on "Metallic Roofing Materials" was opened with a paper on Metallic Roofing, by D. M. Buck, Chief Chemist, American Sheet and Tin Plate Company, Pittsburgh.

The papers on the general subject were presented by J. A. Aupperle, Chief Metallurgical Engineer, with American Rolling Mill Company, Middletown, Ohio; J. A. McEwen, Assistant Engineer, Pittsburgh Bridge & Iron Works.

The discussion was participated in by E. O. Newsome, Treasurer, Asbestos Protected Metal Company, Beaver Falls; J. O. Handy; V. R. Covell; W. G. Wilkins; J. A. Ferguson; A. Stucki; Lee C. Moore; H. J. Lewis; Edward Godfrey; L. F. W. Hildner; J. W. Todd; J. W. Cogley; J. M. Fonse; R. B. Woodworth; J. A. Aupperle; E. O. Newsome, and D. M. Buck.

Meeting adjourned at 10:45 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Friday, November 10th, 1911, at 4:50 P. M., President Riddle presiding, Messrs. Handy, Morse, Lyons, Stucki, Frost, Woodworth and the Secretary being present.

The minutes of the last regular meeting, held October 6, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board on October 6th, were duly elected to membership:

ACTIVE

Gerber, Christian G. Schreiber, J. W.
Town, Frederick E.

ASSOCIATE

Schroth, Albert J.

JUNIOR

Peters, Frank G. Wallace, William S.

White, Andley D.

Applications were received from the following gentlemen and their names ordered published to the Society:

ACTIVE

Bender, F. H. Benner, R. C.
Bunker, Geo. C. Cornelius, H. R.
Fitzgerald, J. M. Foner, N.
Jackson, B. B. Macintire, H. J.
Pendleton, D. D. Popcke, A. G.

JUNIOR

Hunt, Aldridge E. Garlinghouse, L. H.

The death of J. L. Lewis was announced; Mr. Lewis joined the Society in March 1880; died November 6, 1911.

The report of the Secretary, showing the financial condition of the Society at close of business October 31st, 1911, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The following report of the Nominating Committee was presented, approved and ordered published to the Society in the November announcement:

Nov. 2, 1911.

To the Board of Direction,
Engineers' Society of Western Penna.,
Oliver Building, Pittsburgh.

Dear Sirs:

Your Nominating Committee beg to submit the following nominations as the unanimous choice of the Committee as candidates for the several offices to be filled:

President, James O. Handy.
Vice President, S. A. Taylor, (2 yrs.)
Treasurer, A. E. Frost.
Directors, A. L. Hoerr, (3 yrs.)
W. C. Hawley, (3 yrs.)

Respectfully submitted.

NOMINATING COMMITTEE:
Morris Knowles, Chairman,
Samuel E. Duff,
Sumner B. Ely,
Edwin H. Haslam,
W. E. Snyder.

The following letter of resignation from Willis Whited, member of the Board of Direction, was presented by the Secretary:

Nov. 2, 1911.

To the President and Board of Direction of the
Engineers' Society of Western Penna.,
Pittsburgh.

Dear Sirs:

Owing to the fact that I have accepted a position with the State Highway Department, which will require my removal from the city, I hereby tender my resignation as a member of the Board of Direction of the Society, same to take effect at once.

I greatly regret the necessity of taking the step as I have greatly enjoyed my connection with your Honorable Board for a number of years, but as my new location will prevent my taking any part in your proceedings, the necessity for my resignation is obvious.

Yours very truly,
(Signed) Willis Whited.

His resignation was accepted reluctantly, the Board expressing regret that Mr. Whited will be unable to continue to serve as Director and extended congratulations to him upon his appointment as Bridge Engineer with the State Highway Department.

The Board of Direction elected Prof. W. E. Mott as a Director to fill out the unexpired term of Mr. Willis Whited who resigned from the Board.

The report of Wm. M. Welch, delegate from the Society to the Third National Conservation Congress, was presented and approved and the Secretary requested to read same at the November meeting of the Society.

Meeting adjourned at 5:45 P. M.

Elmer K. Hiles,
Secretary.

REGULAR MONTHLY MEETING

The 316th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held as a joint meeting with the Coal Mining Institute of America, in the Society rooms, Oliver Building, Pittsburgh, Tuesday, December 19, 1911, at 8:15 P. M., President Riddle presiding, 140 members and visitors being present.

The minutes of the last regular meeting, held November 21st, were read and approved.

The Board of Direction reported the election of ten Active members and two Juniors; the receipt of nine applications for Active membership, one for Associate, two for Junior and two for Junior-Student grades.

After an address of welcome and greeting to the members of the Coal Mining Institute of America, by Dr. Walther Riddle, President of the Society, the paper of the evening on "Steam Power Plants", written jointly by O. S. Lyford, Jr., Consulting Engineer of the Westinghouse, Church, Kerr & Company, New York, and R. W. Stovel, Mechanical Engineer of the Westinghouse, Church, Kerr & Company of New York, was read by Mr. Lyford.

The ensuing discussion was participated in by Messrs. J. N. Chester, S. A. Taylor, P. M. Lincoln, W. A. Bole, Fred Darlington, E. D. Leland, Prof. W. Trinks, J. A. Hunter, O. S. Lyford, Jr., and R. W. Stovel.

The meeting adjourned at 10:40 P. M.

Elmer K. Hiles,
Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, December 5, 1911, at 8:15 P. M. The meeting was called to order by Vice Chairman Wurts; 125 members and visitors being present.

The minutes of the last meeting, held October 3rd, were read and approved.

No further business coming before the Section, the paper of the evening, "Regenerative Stoves and their Relation to Blast Furnace Practice", was presented by A. N. Diehl, Superintendent Blast Furnaces, Carnegie Steel Company, Duquesne, Pa.

The ensuing discussion was participated in by the following gentlemen: E. L. Messler, General Supt., Blast Furnaces, Jones & Laughlin Steel Co. (absentia); J. A. Mohr, Supt., Carrie Furnaces, Carnegie Steel Co. (absentia); John I. Souther, Supt., Blast Furnace

Dept., Cambria Steel Co., Johnstown, Pa.; Fred Crabtree, Prof. of Metallurgy & Mining, Carnegie Technical Schools; Harry Kennedy, Supt., Blast Furnaces, Clairton Works, Carnegie Steel Company; Carl S. Forkum, Supt. Furnaces, Aliquippa Works, Jones & Laughlin Steel Company; A. E. Maccoun, Supt., Furnaces, Edgar Thomson Works, Carnegie Steel Company; John Dougherty, Vice President, Crucible Steel Company; Kenneth Seaver, Chief Engineer, Harbison-Walker Refractories Co.; J. M. Knote, Assistant Chemist, Pittsburgh Testing Laboratory; R. H. Wilkinson, Supt., Struthers Furnace Co., Struthers, O.; Ralph Atcherson, Bellaire Works, Carnegie Steel Company; H. C. Cronemeyer, Efficiency Engineer, Jones & Laughlin Steel Co., and A. N. Diehl.

The meeting adjourned at 10:45 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Thursday, December 8, 1911, at 4:49 P. M., President Riddle presiding, Messrs. Handy, Taylor, Duff, Mott, Stucki and the Secretary being present.

The minutes of the last regular meeting, held November 10, were read and approved.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board on November 10th, were duly elected to membership:

ACTIVE

Bender, F. H.,
Bunker, Geo. C.,
Fitzgerald, J. M.,
Pendleton, D. D.,
Jackson, B. B.,
Benner, R. C.,
Cornelius, H. R.,
Foner, N.,
Macintire, H. J.,
Popcke, A. G.

JUNIOR

Hunt, Aldridge E.,
Garlinghouse, L. H.

Applications were received from the following gentlemen and their names ordered published to the Society:

ACTIVE

Bishop, Frederick L.,
Coolidge, George G.,
Licht, Jacob C.,
Summers, Edgar W.,
Woodruff, M. B.,
Brosius, E. E.,
Faris, J. M.,
Skewis, J. R., Jr.,
Wilkinson, R. H., Jr.

ASSOCIATE

Hull, Wallace R.

JUNIOR

Abel, Ernest A., Hugo, Victor J.

JUNIOR-STUDENT

Hallock, J. W. W., Everhart, S. D., Jr.

Announcement was made of Mr. Chester B. Albree's proposed gift to the Society of the bust of Plato, and the Secretary was requested to communicate with Mr. Albree, thanking him for his gift.

The matter of representation on the Civic Club of Allegheny County, was taken up and President Riddle appointed Mr. F. Z. Schellenberg to represent the Society on the Civic Club Committee.

Adjourned at 5:45 P. M.

ELMER K. HILES,
Secretary.

PROCEEDINGS

—OF THE—

ENGINEERS' SOCIETY

OF WESTERN PENNSYLVANIA

INCORPORATED 1880

Edited by the Secretary under the direction of the Publication Committee.
Published Monthly, except August and September.

Reprints from this publication, which is copyrighted, may be made by any other publication on condition that the full title of paper, name of author, page reference, and date of presentation to the Society are given. This does not apply to matter under Engineering Data, republication of which is reserved to the Society.

No paper read before the Society shall be published in any magazine or journal before its appearance in the Proceedings, and no paper previously published shall be published in the Proceedings without authority from the Publication Committee.

All papers, on their acceptance by the Publication Committee, become the property of the Society, and it lies within the discretion of the Committee to publish them in whole or in part. This will always be done, if possible, with the approval of the author.

The Society, however, does not hold itself responsible for opinions expressed by its members.

The Society will mail monthly, except August and September, to its members, correspondents and advertisers, postage prepaid, a copy of the Proceedings; each one containing the minutes of, and the papers read at the regular meeting and meetings of the Mechanical. and Structural Sections.

The Proceedings are for sale at the following prices:

1 to 10 copies, 50c apiece.
10 " 50 " 35c "

The author of a paper is entitled to 25 copies of the number containing his paper. He may also have any additional number he desires at ten cents each, *provided they are ordered before going to press.*

Subscription price $5.00 per annum. To colleges and public libraries who agree to bind and catalogue, subscription price is $1.00 per annum.

Back numbers that are becoming scarce are higher. Prices will be quoted by the Secretary.

Back volumes are for sale at the following price: Volumes 1, 5, 6, 7, 8, 9, 10, paper bound, $2.00; cloth bound, $2.75.

Sets of Volumes 11, 12, 13, 14, 15, 16 ready for binding, $2.00; bound in cloth, $2.75.

Volumes 17, 18, 19, 20, 21, 22, 23, 24 and 25, ready for binding, $5.00; cloth bound, $5.75.

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EMPLOYMENT BULLETIN

The Society has found it can do an important work as the medium for securing better positions for its members who desire them. The Secretary gives this his personal attention, and is desirous of receiving prompt notification both of positions open and of men available. Notices are not repeated except upon special request.

MEN AVAILABLE

40 Structural Engineer desires position as assistant to Chief Draftsman, squad boss or checker. Experienced on bridge and structural work.

52 Mining Engineer desires position. Have filled positions as Assistant General Superintendent and Chief Engineer with compony operating a number of coal mines. Large experience on construction work.

76 Recent graduate from Lehigh University, Mech. Engrg., desires position.

79 Wanted: Position as Structural or Contracting Engineer by a graduate engineer with 14 years varied experience in drafting room, shop and office on all classes of structural and plate work. At present holds responsible position with a steel construction company.

82 Rolling Mill and Steel Works Engineer of long experience desires to make change. Capable of laying ont entire plant and designing machinery for same. Would consider taking stock in a manufacturing company.

84 Technical graduate, Civil Engineering, with 2½ years experience in mine, railroad and city work, desires position.

85 Technical graduate Mechanical Engineering, with nine years experience on mill building and bridge work, desires position.

86 Mechanical Draftsman with five years experience, desires position.

87 Expert tracer, quick and accurate, desires position.

89 Detailer and tracer with three years experience in rolling mill work, desires position.

90 Engineer with good experience in civil and mining engineering work, desires position.

91 Young engineer with three years practical experience with open hearth furnaces desires position. Technical education.

92 Electrical engineer with 18 years experience desires position.

Has designed, constructed and operated power, light and telephone plants.

93 Draftsman experienced in structural, mining and railroad work, both office and field, desires position.

94 Civil engineer, technical education, with six years experience in mill, railroad and structural work desires position.

95 Designing draftsman experienced in mechanical and electrical work desires position. Technical education.

96 Mechanical engineer experienced in the design, construction and operation of blast furnaces, steel works, rolling mills and machinery for handling materials in bulk, with first class organization of foremen and assistants for mill and furnace construction, desires position as Mechanical Engineer, or Superintendent of Construction.

97 Young engineer with experience in civil and mining engineering, desires position.

98 Mechanical Engineer for one of the largest operating companies in Pennsylvania desires change of position at once. Six years experience in designing and erecting power plants up to 3000 h. p. and in operating them from department headquarters. Specialist in gas compressing and pipe line problems.

99 Bridge and structural engineer with ten years experience in general structural steel designing, construction and erection, desires position. Technical education.

100 Level and rodman desires position with surveying party. 4½ years experience.

101 Detailer and tracer, four years experience, desires position.

102 Recent technical graduate in civil engineering, desires position.

103 Draftsman, mechanical, desires position, shop experience and technical training.

104 Inspector on structural steel, bridge and masonry work, desires position. Seven years experience, good references.

105 Engineer with several years experience on surveys, railroad. mining and mill work, desires position.

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American Engineer.
American Machinist.
American Society of Civil Engineers, Proceedings.
American Society of Mechanical Engineers, Proceedings.
American Water Works Association, Bulletin.
American Railway Engineering and Maintenance of Way Association, Bulletin.
Analyst, The.
Appleton's Magazine.
Annales de L'Association des Ingenieurs de Grand.
Annaes Scientificos de Academia Polytechnia Porto.
Anales de la Sociedad Cientifica Argentina.

Bi-Monthly Bulletin of Amer. Institute of Mining Eng.
Building Management.

Canadian Electrical News.
Cassier's Magazine.
Chamber of Mines, Monthly Journal of the
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Coal Trade Bulletin.
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Cornell Civil Engineer.

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Electric Railway Journal.
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Electrical World.
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Engineering & Mining Journal.
Engineering News.
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Engineering—Contracting.
Engineers' Club of Philadelphia, Proceedings.
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Mexican Mining Journal, The
Mines & Minerals.

Monthly Journal of the Chamber of Mines.
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National Engineer.

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Official Journal, Patents, (London).
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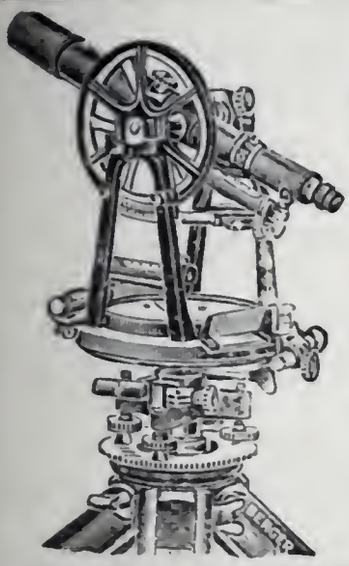

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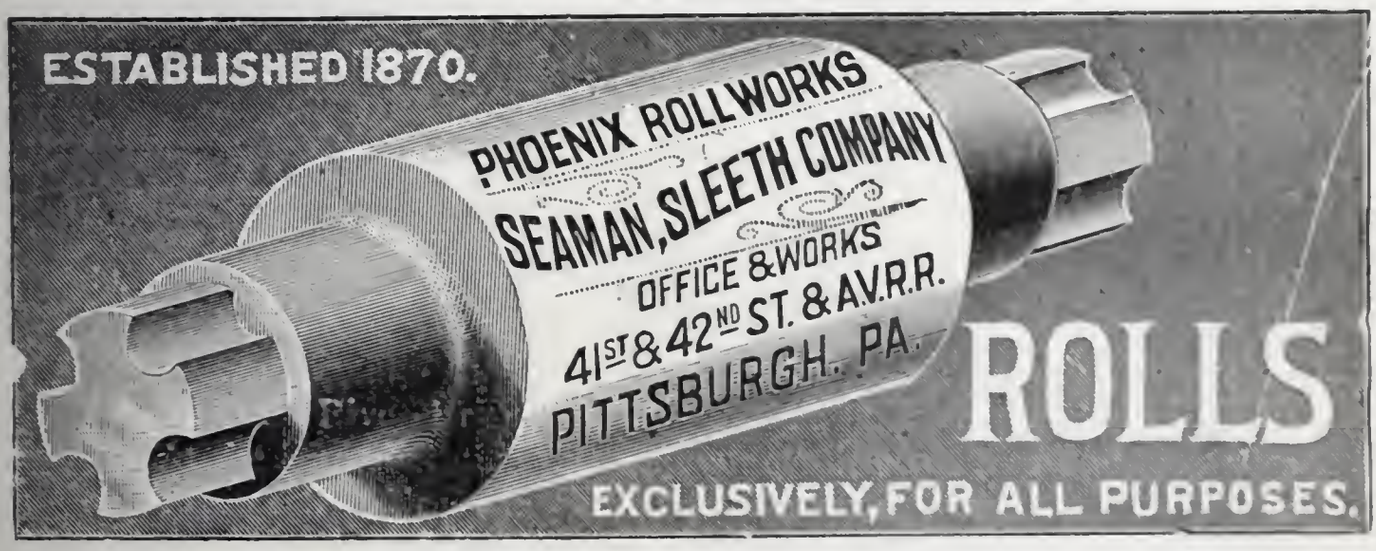

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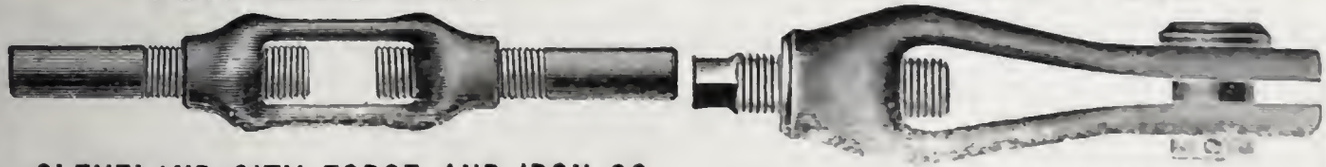

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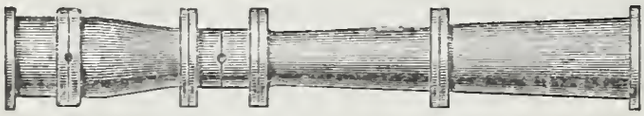

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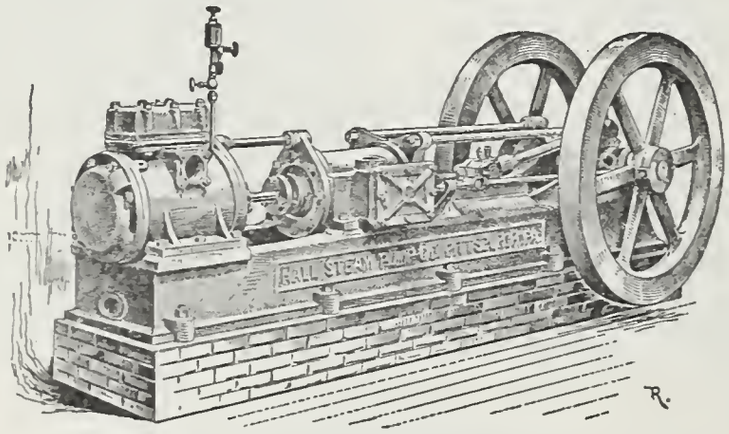

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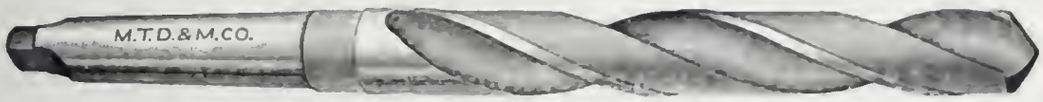

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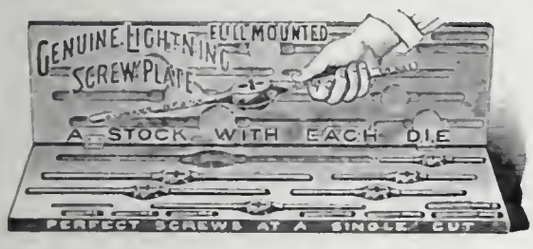

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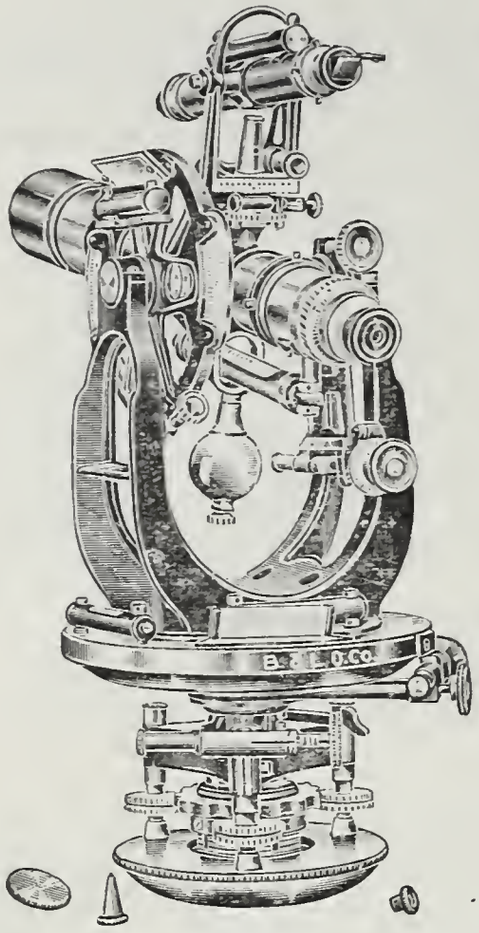

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